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Scallop Fishing Area 29: Stock Status and Update for 2014

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

This scallop fishery has taken place in the portion of Scallop Fishing Area (SFA) 29 west of longitude 65º30'W since 2001 and is currently fished by two fleets: the Full Bay Fleet and limited number of inshore East of Baccaro licence holders. As of 2010, the Total Allowable Catch (TAC) and landings are reported as totals by subarea for both fleets combined. In 2013, a total of 154.4 t was landed against the TAC of 170 t. There was an additional Food, Social and Ceremonial catch of 4.9 t. A new framework assessment methodology was accepted in February 2014 that uses a habitat-based population model for subareas A–D. The model is based on a scallop habitat map and this map does not cover subarea E.

From the survey in 2013, commercial densities were similar across habitat suitability categories within subareas A–D and either declines or no change were observed. For recruit densities, either declines or no change were observed for all habitat suitability categories in subareas A–D. An increase in pre-recruits (20–60 mm) was observed in subareas A–D; however, the highest values were mainly concentrated in subareas C and D. These pre-recruit numbers are the highest observed in the time series and, based on growth estimates, are not expected to recruit to the fishery until 2016.

Current densities (2 to 2.3 t/km^2 in the High habitat category, 1.5 to 1.8 t/km^2 in the Medium habitat category) appear to represent an approximate equilibrium level with respect to recent exploitation and recruitment rates. In the absence of increases in the rate of recruitment, continued fishing at the recent levels in the Medium and High suitability areas will likely result in densities remaining in the ranges that they have been since 2006. Assuming the same catch in 2014 as in 2013, and that the same fishing pattern with respect to habitat suitability areas occurs in 2014, current levels of exploitation will probably result in little change in biomass in 2014. However, densities in the High and Medium habitat categories are currently at or near their lowest values in the time series.

Zone de pêche 29 du pétoncle: état du stock et mise à jour pour 2014

RESUME

La pêche du pétoncle considérée ici se déroule dans la partie de la zone de pêche du pétoncle (ZPP) 29 située à l'ouest de la longitude 65° 30' O depuis 2001; elle est actuellement pratiquée par deux flottilles, soit la flottille de la totalité de la baie et un certain nombre de titulaires de permis de pêche côtière pour l'est de Baccaro. Depuis 2010, le total autorisé des captures (TAC) et les débarquements sont totalisés par sous-zone pour l'ensemble des deux flottilles. En 2013, les débarquements totaux se sont chiffrés à 154,4 t, par rapport à un TAC de 170 t. De plus, les captures à des fins alimentaires, sociales et rituelles se sont chiffrées à 4,9 t. Une nouvelle méthode d'évaluation du cadre a été acceptée en février 2014. Cette méthode utilise un modèle de population fondé sur l'habitat pour les sous-zones A à D. Le modèle est fondé sur une carte de l'habitat des pétoncles, et cette carte ne couvre pas la sous-zone E.

D'après le relevé en 2013, les densités commerciales étaient semblables dans l'ensemble des catégories d'habitats propices des sous-zones A à D, et l'on a observé des déclins ou l'on n'a observé aucun changement. Pour ce qui est des densités des recrues, on a observé des déclins ou l'on n'a observé aucun changement dans toutes les catégories d'habitats propices des sous-zones A à D. On a constaté une augmentation du nombre de pré-recrues (de 20 à 60 mm) dans les sous-zones A à D. Cependant, les valeurs les plus élevées sont principalement concentrées dans les sous-zones C et D. Ce nombre de pré-recrues est le plus élevé dans la série chronologique, et selon les estimations de croissance, il est prévu que ces pré-recrues ne soient pas recrutées à la pêche avant 2016.

Les densités de courant (2 à 2,3 t/km^2 dans la catégorie d'habitat de qualité élevée, 1,5 à 1,8 t/km^2 dans la catégorie d'habitat de qualité moyenne) semblent représenter un niveau d'équilibre approximatif quant aux récents taux d'exploitation et de recrutement. S'il n'y a aucune augmentation du taux de recrutement, les niveaux de densité ne devraient guère changer par rapport à ceux enregistrés depuis 2006 par suite de la poursuite de la pêche aux récents niveaux de densité dans les zones de qualité moyenne et élevée. Si le niveau des captures est le même en 2014 qu'en 2013, et que les mêmes habitudes de pêche en ce qui concerne les zones d'habitats propices sont adoptées en 2014, les niveaux d'exploitation actuels entraîneront probablement peu de changements en matière de biomasse en 2014. Toutefois, les densités dans les catégories d'habitat de qualité moyenne et élevée sont actuellement à leurs valeurs les plus faibles ou presque dans la série chronologique.

INTRODUCTION

Scallop Fishing Area (SFA) 29 encompasses a very large inshore area inside the 12-mile territorial sea, from the south of Yarmouth (latitude 43°40'N) to Cape North in Cape Breton (Figure 1). This report refers to only that portion of SFA 29 west of longitude 65°30'W continuing north to Scallop Production Area 3 at latitude 43°40'N (hereafter referred to as SFA 29 West). This area is fished by the Full Bay fleet and inshore East of Baccaro licence holders who are authorized to fish in SFA 29 West.

The history of fishing in this area up to 2001 can be found in Smith and Lundy (2002). A review of the three-year joint project agreement signed in 2002 with the two fishing fleets, Natural Resources Canada, and Fisheries and Oceans Canada (DFO) with all parties providing funds to conduct multibeam acoustic mapping of the seafloor and other scientific work was reported in DFO (2006). Using the multibeam data and associated derived layers, Brown et al. (2012) developed a scallop habitat suitability map which covered SFA 29 West subareas A–D (Figure 2). This map has formed the basis for the new assessment model for SFA 29 West.

This report follows the framework methodology outlined in Smith et al. (*in press*) and summarizes commercial fishery, research survey, and observer data for the 2013 fishery and provides advice for the 2014 fishery. A summary of lobster and all other bycatch recorded by observer coverage is provided. The scallop fishery in this area was last assessed in 2013 (Smith et al. 2013).

COMMERCIAL FISHERY

The fishery management plan sets a 100 mm minimum shell height for retained scallops. In this report, scallops with shell height 100 mm and greater will be referred to as fully-recruited or commercial size and 90–99 mm scallops will be referred to as recruits and are expected to grow to be commercial size in the following year.

The 2013 fishery opened on June 24, 2013, with a total quota of 170 t allocated over subareas A B, C, D and E (Table 1). Subarea D closed on July 11, 2013, and subarea B closed on July 19, 2013, as the quota had been caught or exceeded in those two subareas. The remaining areas were closed on August 31, 2013, with 15.6 t of Total Allowable Catch (TAC) left uncaught. The final total catch was 159.3 t and included 4.9 t of Food, Social, and Ceremonial (FSC) catch that does not count against the TAC. There were no closed areas in 2013 as a result of lobster bycatch.

COMMERCIAL CATCH RATE

As in previous years, to improve the accuracy of catch rates and effort (where effort is calculated from the reported number of tows and average tow time), DFO Science reviewed the commercial log data from SFA 29 West in 2013. This process results in increasing the percentage of usable log records over those originally reported. For 2013, all log data were validated against the original paper logs and missing location data were recovered when possible through the use of Vessel Monitoring System (VMS) and hail data. This resulted in 100% of logs being used for catch rate estimates for 2013 (Table 2).

Subarea A has been fished sporadically by the East of Baccaro fleet and more consistently by the Full Bay fleet. From 2012 to 2013, catch rates in this subarea declined slightly for the Full Bay Fleet, whereas it increased slightly for the East of Baccaro fleet (Figure 3). However, catch rates from both fleets in subarea A are similar (approximately 10 kg h^{-1}) and are the lowest of all the subareas. In subarea B, catch rates remained relatively similar between 2012 and 2013 for

both fleets and were approximately 26 kg h^{-1}. For subarea C, the Full Bay catch rate remained relatively stable between 2012 and 2013, whereas an increase occurred for the East of Baccaro fleet. Catch rates in C were 19 kg h^{-1} and 24 kg h^{-1} for the Full Bay and East of Baccaro fleets, respectively. In subarea D, from 2012 to 2013, both fleets observed a similar increase in catch rates to 34 kg $h^{-1}$and 29 kg h^{-1} for the Full Bay and East of Baccaro fleets, respectively. In subarea E, prior to 2012 the catch rate series for both fleets had been relatively similar but diverged in 2012. In 2013, the catch rates for both fleets have re-converged and were approximately 25 kg h^{-1} (Figure 3).

The extent of spatial variability in fishing location in 2013 relative to 2012 varied depending on the subarea. In subarea A, the fishing in 2013 took place in three very localized areas, only one of which was fished in 2012 (Figure 4). In contrast, from 2012 to 2013, the area covered by the fishery was relatively consistent in subareas B, D and E. However, in subarea C, the distribution of fishing in 2013 was greatly contracted relative to 2012 (Figure 4).

VESSEL MONITORING SYSTEM (VMS)

VMS can be used to provide high resolution information on fishing activities; however, since VMS data do not indicate if a vessel is fishing, speed criteria are often used to differentiate between activity states (e.g. fishing, steaming) and derived effort indices. Monitoring fishing activity using VMS has been a mandatory requirement for the inshore scallop fishery in SFA 29 West since the fishery began in 2001; however, the data has only been recorded by the Department since 2002. VMS data consists of a vessel name, vessel registration number (VRN), date-time stamp, and position in decimal degrees (World Geodetic System 1984). Vessels are not required to transmit their speed, therefore, derived speeds, calculated from the positions and time differences between successive VMS records are used. Fishing was identified based on a speed criterion as defined by Smith et al. (*in press*). For SFA 29 West, from 2002 to 2009, VMS was polled at 60-min, and since 2010, polling has been at 15-min. For consistency, all VMS data from 2010-2013 were resampled to 60-min. To compare VMS to the scallop habitat suitability map, habitat suitability values were binned into 10 intervals of width 0.1 and the spatially coincident habitat bin values associated with each VMS record were determined.

The spatial distribution of VMS can resolve fine scale patterns in fishing effort. In SFA 29 West, there are clear patterns in fishing distribution (Figure 5). The fishery is quite patchy in subarea A, with very little fishing occurring in the southern third of the area. In subareas B, C and D, consistently fished areas are readily identifiable and much of the area has been fished (Figure 5). In contrast, most of subarea E has not been fished. Fishing in this subarea has mainly been limited to the area along the border with B, with a few localized areas also having been fished towards the outer border of E (Figure 5).

Fishing effort per area or fishing intensity was consistently higher in the higher suitability areas over all of the subareas except subarea A (Figures 6–9). This trend is relatively consistent across all years including 2013. When habitat suitability is binned into three categories defined by Low [0, 0.3), Medium [0.3, 0.6), and High [0.6, 1.0), the pattern of higher fishing intensity in the higher habitat suitability areas in also apparent (Figure 10). Additionally, for subareas A, B and C, the proportional allocation of effort with respect to habitat suitability over time, including 2013, has been relatively stable demonstrating the persistent harvesting of these different types of areas (Figure 11). In subarea D, the proportional allocation of effort decreased in the High areas and increased in the Medium areas from 2004 to 2009; however, the proportional allocation has been relatively similar since 2009 (Figure 11).

RESEARCH SURVEY

Annual surveys in SFA 29 West have been conducted since the start of the current fishery in 2001. The survey occurs in September/October after the fishery has closed. The initial survey in 2001 used a simple random design over the whole area. From 2002 to 2004, a stratified random design was used with strata defined by the management subareas A to E. Starting in 2005, strata were defined by bottom type as identified by geologists as part of the joint industry/government multibeam mapping project conducted in this area (DFO 2006). A new interpretation of the bottom types was made available in 2008 (Todd et al. 2009) and was used to design the surveys for 2008 through 2013. The new assessment approach (Smith et al. *in press*) uses the scallop habitat suitability map developed by Brown et al. (2012) and bins habitat suitability probabilities into three categories defined by the following ranges: Low [0, 0.3), Medium [0.3, 0.6), and High [0.6, 1.0). From Brown et al. (2012), habitat suitability probabilities range from 0 to 1 and represent a relative scale of suitable scallop habitat, with the lowest suitable scallop habitat indicated by 0 and the highest suitable habitat indicated by 1. Survey estimates from 2001 to 2013 were modified to correspond to the design based on these three categories of habitat suitability probabilities (Smith et al. *in press*). In 2013, 120 tows were conducted in SFA 29 West (A–E).

Subarea E has not been consistently covered in the survey due to time limitations; this subarea is considered to be marginal habitat for scallops and, as a result, has been less of a survey priority. Prior to 2012, this area had not been surveyed since 2005. In both 2012 and 2013, five exploratory tows were conducted in subarea E in areas known to have been regularly fished. Subarea E is also not covered by the habitat suitability map by Brown et al. (2012). Details on the history of the survey from 2001 to 2012 can be found in Smith et al. (*in press*).

ABUNDANCE INDICES

Stratified mean number and weights of meats per tow were calculated within categories (Low [0, 0.3), Medium [0.3, 0.6), and High [0.6, 1.0)) of habitat suitability probabilities for subareas A through D. Previous survey designs were accounted for in the habitat suitability stratified estimates and detail can be found in (Smith et al. *in press*). Simple mean numbers per tow were calculated for subarea E.

Shell height frequencies for subareas A through E are presented in Figures 12–16 and numbers per tow for various size classes are in Figures 17–21. For subareas A–D, the use of habitat suitability provides clearer patterns of the population dynamics than previous survey designs (Figure 17). In subareas A–D, an increase in pre-recruits size (approximately 20–60 mm) was observed in 2013, with significantly greater numbers per tow observed in subareas C and D. Within subareas C and D, the greatest numbers per tow were observed in the High habitat suitability category, followed by the Medium, then Low categories (Figures 12–15, 20). Although the size range of these scallops is near the limit of the survey gear (38-mm mesh), the numbers of pre-recruits observed in the 2013 survey in subareas C and D are the highest observed in the time series (Figure 20). The 2014 survey will provide a more quantitative determination of the strength of this year-class. These pre-recruits are expected to recruit to the fishery in 2016.

In 2013, the number of commercial sized scallops (≥ 100 mm) per tow remained the same in the Medium suitability category and decreased in the Low category in subarea A (Figure 18). In subarea B, the number of commercial sized scallops in 2013 is similar across all three suitability categories; however, there was a decline in the number per tow between 2012 and 2013 for the High and Medium categories (Figure 18). In subarea C, the number of commercial sized scallops in 2013 is similar between the High and Medium categories; however, a decline in number per tow was observed between 2012 and 2013 in the High and Low categories

(Figure 18). In subarea D, the commercial number per tow had increased in 2012 in the High suitability category; however, this has since decreased in 2013 along with a decrease in the Medium category. Commercial numbers per tow in subarea D in 2013 are the most similar they have been between suitability categories in the time series (Figure 18).

In 2013, the number of recruit sized scallops (90–99 mm) per tow decreased in both the Medium and Low suitability categories in subarea A (Figure 19). In subarea B, there was a slight decrease in the numbers of recruits from 2012 to 2013 in the Medium and Low categories, whereas the number per tow in the High suitability category remained relatively constant. However, the number of recruits per tow in the High category is similar to that of the Low category (Figure 19). In subarea C, the number per tow of recruit sized scallops decreased in the High category from 2012 to 2013 and is currently similar to levels observed in the Medium and Low categories, whereas recruit numbers per tow in 2013 in the Medium and Low categories are similar to 2012 (Figure 19). In subarea D, the number of recruit scallops per tow has been similar between habitat suitability categories since 2011 and remained similar in 2013. However, recruit numbers are similar between the habitat categories.

Five exploratory tows were conducted in subarea E in 2012 and again in 2013 in known fishing locations near the border with subarea B. In 2013, a peak in pre-recruits in the range of 15–45 mm was observed, and another mode of commercial sized animals was also observed (Figure 16). Observed numbers per tow were 146 and 11 for commercial and recruit sizes, respectively.

The mean number of commercial sized clappers (paired empty shells used as indicators of natural mortality) in the survey has been low and similar between habitat suitability categories within subareas since 2005 in subarea B, since 2006 in subareas A and C, and since 2009 in subarea D (Figure 21). In subarea E, commercial sized clappers were observed in 2012 (approximately 2 per tow) but were not observed in 2013.

The survey mean weight per tow of commercial sized animals in subarea A was similar to that of 2012 in the Medium habitat suitability category but decreased in the Low category (Figure 22). In subarea B, commercial mean weight per tow decreased in the High and Medium categories, whereas no change was observed in the Low category in 2013. In subarea C, a decrease was observed across all habitat suitability categories in 2013, with the largest decrease observed in the High category. In subarea D, decreases in mean weight per tow in 2013 were observed in the High and Medium categories, whereas a slight increase was observed in the Low category (Figure 22).

GROWTH AND CONDITION

In scallop fishing areas in the Maritimes Region, Canada, where assessment models are used, biomass growth is an important component of the population models. It has been noted in previous assessments (e.g. Sameoto et al. 2012, Smith et al. 2013) that the relationship between meat weight and shell height (condition) shows a great deal of spatial and temporal variability. In this assessment, spatial patterns of growth and condition were examined and, in the case of condition, incorporated into the model estimates of biomass. A detailed description of how growth and condition are calculated and incorporated into the assessment model can be found in Smith et al. (*in press*).

The annual trend in condition factor increased in 2013 in subareas A and D, with the largest increase observed in D. Condition decreased in 2013 in subareas B and C, but the decrease in C was relatively small (Figure 23). Spatially, condition was much higher across subareas D and part of C than in subareas A, B or E in 2013 (Figure 24). It is important to consider spatial

abundance patterns when placing spatial condition patterns in context. Commercial abundance, in addition to being generally low, is also fairly patchy in SFA 29 West. Areas with relatively high abundance (≥ 100 scallops per tow) can be found throughout each subarea; however, the extent of these abundances is greater in subareas A and B. A single localized area of very high abundance (≥ 500 scallops per tow) was observed in subarea B (Figure 25). Recruits are generally sparsely distributed with very few recruits in subarea D (Figure 26). Pre-recruits were found in very high abundances (generally ≥ 300 scallops and some areas of ≥ 500 scallops per tow) throughout subarea A, in almost half of subarea C, and in parts of subarea D. Pre-recruit abundance was generally ≤ 100 scallops per tow in most of subarea B and the surveyed portion of subarea E (Figure 27).

The combination of spatial patterns of condition and abundance can be used to predict the spatial distribution of meat count. The predicted meat count of commercial sized animals (≥ 100 mm) for SFA 29 West was generally low, mainly below 20 meats/500 g in the eastern portion of subarea C and throughout subarea D. Predicted commercial meat count in subareas A and B were generally below 30 meats/500 g (Figure 28). Low meat counts, particularly those observed in subarea D, are due to a combination of factors including that the commercial size class consists mainly of large scallops and there was an increase in condition in 2013 (Figures 24, 28).

Annually varying growth rates for the biomass of commercial size scallops were calculated using a von Bertalanffy growth equation for shell growth and the change in condition factor from year to year (Sameoto et al. 2012). The resulting annual observed growth factor was quite variable (Figure 29). It is also important to note that occasionally the growth factor is at, or below 1 which would indicate zero growth. This situation has been observed numerous times across subareas A though D throughout the time series. From 2012 to 2013, growth rate remained relatively similar over the Medium and Low habitat suitability categories in subarea A, decreased significantly (between 30–40%) in each habitat category within subareas B and C, and increased (approximately 10%) in each habitat category in subarea D (Figure 29).

ASSESSMENT MODEL

HABITAT-BASED POPULATION MODEL

The state-space habitat-based assessment model as defined by Smith et al. (*in press*) was fit to the commercial catch, VMS effort, and survey data. The model was fit within each habitat suitability category within each subarea. The basic model is a simplification of the delay-difference model and is detailed in Smith and Hubley (2014). Annual rates of natural mortality were modelled from trends in the clapper index (hinged empty shells) using the "popcorn" model described in Smith and Lundy (2002) and annual growth rate for biomass was estimated by the method described in Nasmith et al. (2013).

Smith et al. (*in press*) demonstrated that areas with the higher habitat suitability for scallops are also areas that have higher densities, especially at the beginning of the fishery; however, these areas do not necessarily account for the highest portion of the biomass as they represent a low proportion of the total area. The population biomass estimates (Figure 30) indicate that the high biomasses tend to occur in the Medium suitability category; however, biomass density was much higher in the High suitability category at the beginning of the fishery and has been reduced over time to be more similar to densities found in the Medium and Low suitability categories (Figure 31). In subarea A, in 2013 commercial biomass densities were similar to those in 2012 with densities in the Medium category remaining below those observed in the Low category. In subarea B, commercial biomass densities in 2013 in the High category are similar

to those of the Low and Medium categories. In subarea C, commercial biomass density decreased from 2012 to 2013 in the High category but is above the Medium and Low categories. In subarea D, commercial biomass densities remained similar from 2012 to 2013 across all three habitat categories (Figure 31).

The population recruit number density estimates indicate that recruit densities are low across all subareas A–D and these numbers are similar across habitat categories with the most recruits in the Medium category of subarea B (Figure 32). In subarea C, an increase in recruit density in the High category occurred in 2012; however, in 2013, recruit density decreased and is now similar to numbers in the Low and Medium categories (Figure 32).

The estimates of natural mortality for the commercial size scallops have been relatively variable over the time series but indicate that higher rates occurred in the earlier years of the fishery (Figure 33). In 2013, natural mortality increased in the Low category in subareas A and D, and also increased in the Medium category in subarea C. However, these increases are well within ranges previously observed. For all other categories within subareas, estimates of natural mortality were relatively similar in 2013 to those for 2012 (Figure 33).

Estimates of commercial catch by habitat suitability show that catch was similar in both the Medium and Low categories in subarea A in 2013 (Figure 34). In subarea B, the majority of catch was estimated to have been taken from the Medium category in 2013. Within subareas C and D, similar amounts of catch were taken from both the High and Medium categories. Commercial catch rates estimated from the model exhibit a similar trend to the estimates of catch (Figures 34, 35). In 2013, in subarea A, estimated catch rates decreased in the Medium category, but are still above rates observed in the Low category. In subarea B, estimates of catch rates in the High category decreased and are similar to catch rates observed in the Medium category. In subareas C and D, catch rates increased in the High categories in 2013 and are above the catch rates in the Medium and Low categories (Figure 35). The catch rates from the subareas as a whole more closely resemble those in the Medium suitability area and resemble the observed commercial catch rates obtained from logbook data (Figure 3, 35).

Exploitation trends by habitat suitability (Figure 36) reflect the fishing intensity trends from the VMS data (Figure 10) with the higher exploitation rates in the High suitability categories for subareas B–D and in the Medium category for subarea A (Figure 36). This pattern of differential exploitation by habitat category remained in 2013, with increases in exploitation in the High suitability category observed in subareas C and D (Figure 36).

The model fit was evaluated three ways. The first was by comparing the means and medians from the posterior predictive distributions for the survey estimates with the actual survey estimates (Figures 37–39). Overall, the mean and median survey estimates fit quite closely to the observed estimates for commercial size biomass, recruit numbers, and survey clappers, with the exception of commercial size biomass in subarea D in 2001. In this case, the model estimated a higher commercial biomass index than observed in 2001 to account for the increase in the commercial biomass index in 2002 despite the high clapper index in 2002 reflecting mortality from 2001 to 2002 and the low recruitment in 2001 (Figure 37).

Another way to evaluate the model was to evaluate the impacts of the prior distributions used. A comparison of prior and posterior distributions for $\log(K)$, S, q and process error indicate that, with the exception of the posterior for q in subarea A, the priors for all the parameters were uninformative, implying that there was enough information in the data to estimate these parameters (Figures 40–43). The final evaluation was to look at the mean posterior process residuals (Figure 44). There was no clear pattern in the residuals but larger process error were observed in the earlier part of the time series in the Low habitat category in subareas B–D,

although the magnitude of these errors decreased in the latter part of the time series (Figure 44).

OTHER ESTIMATES OF EXPLOITATION

DEPLETION MODEL

Previous assessments of SFA 29 West have estimated exploitation rates using the depletion model described by Leslie and Davis (1939) (Sameoto et al. 2012, Smith et al. 2013). For comparison with the habitat-based population model, annual estimates of exploitation from the depletion method were conducted in subareas A to D. The model was cast as a hierarchical Bayesian model that shared information across years in order to mitigate issues that arise when there is insufficient data to show a distinct decline of catch rates in response to removals. The information shared was with respect to the catchability coefficient and the model was fit to the daily catch rates and incorporated standard errors derived from jackknife estimates. Further details on this model can be found in Sameoto et al. (2012).

SURVEY MODEL

Exploitation estimates calculated from the annual trends in survey biomass have been presented in previous assessments of SFA 29 West and details on the method used can be found there (Smith et al. 2010, Sameoto et al. 2012). The exploitation estimate from the survey method is a combined term reflecting both natural and fishing mortality (Sameoto et al. 2012, Smith et al. 2013).

COMPARISON OF MEANSURE OF EXPLOITATION

A comparison of the subarea estimates of exploitation from the assessment model, the depletion model, the survey model, and the annual trend in commercial effort can be found in Figure 45. Depletion estimates of exploitation are reflective of local depletions in contrast to the other three series. The trend in the subarea exploitation rate from the habitat-based assessment model was closest in agreement with the effort index (Figure 45). A more formal comparison of the correlation between the state-space habitat-based assessment model exploitation estimates and estimates from methods used in previous assessments can be found in Smith et al. (*in press*).

STOCK STATUS AND ADVICE FOR 2014

Biomass projections for the state-space model from the current year to the next year are obtained from the posterior distributions generated by the process model for a given catch assuming that current year estimates of natural mortality and growth rates apply. The performance of the model's prediction of biomass in the following year was evaluated by comparing predictions from fits to the data up to year $t-1$ (e.g. 2012) to year t (e.g. 2013) with the estimates of biomass from fitting the model to data up to and including year t. All of the biomass estimates for the current year from 2010 to 2013 fell within the 80% credible intervals of the projected biomass for all of the subareas, with the exception of the High suitability areas in subarea D in 2012 and subarea C in 2013 (Figures 46–49).

Assuming the same catch in 2014 as in 2013, and that the same fishing pattern with respect to habitat suitability areas occurs in 2014, exploitation, percent change in commercial biomass, and the probability of biomass decline were determined from the model and are presented in Table 3. Given the aforementioned assumptions, current levels of exploitation will probably result in little change in biomass in 2014. However, densities in the High and Medium habitat categories are currently at or near their lowest values in the time series.

Although Table 3 indicates that similar catch levels can be taken from subareas C and D in 2014 with a relatively low risk of decline, the presence of significantly high levels of pre-recruits in the area should be considered in conjunction with Table 3. An increase in pre-recruits (approximately 20–60 mm) was observed in subareas A–D; however, the highest values are mainly concentrated in subareas C and D. In subareas C and D, the observed numbers in pre-recruits are the highest observed in the time series and the highest densities are located in the High suitability areas. Based on growth estimates, these scallops are not expected to recruit to the fishery until 2016.

Long-term expectations for catches were estimated in the framework meeting (Smith et al. *in press*) based on assuming constant recruitment set to the median of the observed time series for each habitat suitability area within each management subarea. Candidate catches were calculated based on equilibrium biomass levels obtained from fishing at one out of a range of fixed exploitation rates over a period of 50 years. The equilibrium biomass levels represented conditions where recruitment, and to a much lesser extent growth, balanced out removals due to the fishery and natural mortality. The simulation model used to estimate the equilibrium catches required a number of simplifying assumptions that may not have been realistic over the range of conditions considered and in practice; one major difference being that the SFA 29 West fishery has not operated under a constant exploitation regime.

However, phase plots comparing exploitation and density estimated from the assessment model for the Medium and High suitability categories for each subarea do reflect aspects of the behaviour observed in the simulations, especially in the case of the high suitability areas (Figure 50). That is, high exploitation rates at the beginning of the time series in the high suitability areas exceeded the populations' ability to compensate for fishery removals via recruitment until densities had declined to around 2 to 2.3 t/km^2. The densities did not decline for the first two years of the fishery in subarea D (2004 and 2005) due to the recruitment of a large year-class at the same time and low exploitation in 2005; however, the densities did decline after the 2006 fishery. These densities appear to represent a rough equilibrium level with respect to the recent exploitation and recruitment rates. The declines for the medium suitability areas were not as great (except for subarea C)m and densities have ranged from 1.5 to 1.8 t/km^2 since 2006, at a level where on average recruitment appears to balance out removals.

In the absence of increases in the rate of recruitment, continued fishing at the recent levels in the Medium and High suitability areas will likely result in densities remaining in the ranges that they have been since 2006. The observed high levels of pre-recruits could result in increased densities of commercial size animals starting in 2016, especially in the high suitability areas. Management of the fishery for 2016 and subsequent years will have to choose between either increasing exploitation in response to the higher densities or fishing at lower fixed exploitation rate. In the former case, densities are likely to drop back to the current levels while in the latter case it may be possible to find equilibrium points at higher densities than the current levels. While the initial catches in the latter choice may not be as high as in former case, catches and catch rates should be higher over the mid-term if exploitation can be balanced with the recruitment rates.

OTHER CONSIDERATIONS

LOBSTER CATCH IN THE SURVEY

Information on lobster caught in the SFA 29 West survey has been recorded since 2001. The spatial distribution of lobster caught in the 2013 survey is displayed in Figure 51. The lobster data were standardized to a tow length of 800 m and width of 5.334 m, and the mean numbers

per tow were calculated within subarea using strata based on geophysical bottom types (Todd et al. 2009). The mean number of lobster per tow has varied over time in all subareas (Figure 52). In 2013, the mean lobster per tow from the survey was 3.4, 2.9, 0.5, 0.2, and 1.8 in subareas A, B, C, D, and E, respectively.

LOBSTER CATCH IN THE FISHERY

The level of observer coverage has been variable over the history of this fishery. Observer coverage can be characterized in terms of the number of observed tows, number of days observed and the number of observed trips. In 2013, there were 1,081 observed tows (199 East of Baccaro and 882 Full Bay), 46 days observed (9 East of Baccaro and 37 Full Bay and 12 trips observed (2 East of Baccaro and 10 Full Bay). There was one East of Baccaro trip that was not included in the dataset as it set out only once and then had to return to shore.

As in previous years, most lobsters caught during the observed fishing trips were in subarea B followed by area C (Table 4, Figure 53).

The methodology for estimating lobster bycatch has changed from previous years. Previously, all scallop caught during an observed trip was used to prorate the number of lobsters. For this year's calculations, only the scallops caught during the associated observed tows were used. To estimate the total number of lobsters caught during the SFA 29 West scallop fishery, the number of lobsters caught during observed trips was converted to a number per ton of observed scallop catch in each subarea of SFA 29 West. This was then multiplied by the total scallop catch in each subarea. It was assumed that the number of lobsters caught in each observed trip was representative of the whole fishery.

In 2013, it was estimated that 15,385 lobsters were caught during the SFA 29 West scallop fishery. This relates to a weight of approximately 8.9 t using the average observed carapace length (90 mm) and average weight of a lobster (0.58 kg) caught in SFA 29 West in 2012 and 2013. This number is almost three times the average estimates from 2012, but is similar to estimates for previous years. The estimate for subarea A (8,436 lobsters) was anomalously high compared to previous years and is not considered reliable due to the low rate of observer coverage and the low number of lobsters actually observed. However, even with the high estimate the estimated number of lobster caught represents < 0.1% of the lobsters caught in the 2012/2013 LFA 34 lobster fishery and 0.2% of the lobsters caught in the area of LFA 34 corresponding to SFA 29 West.

The number of dead or injured (DI) lobsters was estimated using the observed percentage of dead or injured lobsters in each subarea of SFA 29 West and applying this to the estimated number of lobsters caught. In 2013, the estimated DI was 2,286. This is considerably higher than 2012 but comparable with the average DI for previous years. In 2013, the highest level of dead or injured lobster was in subarea B at 954.

As far as the direct effects of the scallop fishery on the lobster stock, the only information available was the catch during the scallop fishery and the scallop survey. There were no available data on how any bottom impacts might affect the lobster population. Some progress has been made on an analysis of underwater images to evaluate associations between lobster and habitat. This analysis indicates that there are significant associations between lobster and habitat, with lobsters more evident on coarse bottoms than on gravel pavements typically associated with scallops (Tremblay et al. 2009).

Indirect information on the effect of the scallop fishery comes from trends in the lobster landings by the directed lobster fishery in LFA 34 (Table 5). Trends in lobster catches by the lobster fishery in the SFA 29 West area as a whole are not indicative of an area that has been

adversely affected by the scallop fishery since 2001. Lobster landings in the area corresponding to SFA 29 West have increased steadily over the past several years and are up 18% over five years. Landings in the area adjacent to SFA 29 West have also increased and are up 15% over the last five years. LFA 34 lobster landings were the second highest in history for the 2012-13 season at 22,775 t.

The lobster landing trends are consistent with the idea that the scallop fishery has not had a negative effect on the lobster fishery, but it is recognized that trends in landings by themselves cannot confirm there has been no effect.

OTHER CATCH IN THE FISHERY

At-sea observer coverage to monitor bycatch of fish and invertebrate species by the inshore scallop fleet is a mandatory part of the management of SFA 29 West. Observed trips from SFA 29 West were used to evaluate the discard rate from the inshore scallop fishery in the area (Table 6). The discard rate is defined as the sum of bycatch species weight from the observed trips divided by the sum of landed scallop weight from observed trips (Sameoto and Glass 2012). Data collected from 12 trips in 2013 were used to update the data presented in Sameoto and Glass (2012). At-sea observer protocols and analysis methods were consistent with previous reports (Sameoto and Glass 2012, Smith et al. *in press*).

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TABLES

Table 1. Commercial scallop fishery landings, total allowable catch (TAC), and landings for Food, Social and Ceremonial purposes (FSC) by First Nations (meats, t) for Scallop Fishing Area (SFA) 29 West from 2010 to 2013. TAC for subareas A and E are combined. Dash (-) indicates no catch.

Year	Subarea	TAC (t)	Landings (t)	FSC (t)	Total Landings (t)
2010	A	25.0	9.4	-	9.4
	E		5.4	-	5.4
	B	65.0	50.7	1.4	52.1
	C	45.0	60.6	-	60.6
	D	65.0	72.1	4.5	76.6
	Total	**200.0**	198.2	**5.9**	**204.0**
2011	A	25.0	18.1	-	18.1
	E		5.6	-	5.6
	B	65.0	59.3	-	59.3
	C	45.0	45.5	-	45.5
	D	65.0	65.7	5.4	71.1
	Total	**200.0**	194.1	**5.4**	**199.5**
2012	A	25.0	1.0	-	1.0
	E		17.9	-	17.9
	B	60.0	76.8	4.2	81.0
	C	45.0	39.8	0.03	39.8
	D	30.0	31.7	0.4	32.2
	Total	**160.0**	167.2	**4.7**	**171.9**
2013	A	35.0	1.3	-	1.3
	E		13.5	-	13.5
	B	75.0	82.6	4.9	87.5
	C	25.0	18.3	-	18.3
	D	35.0	38.8	-	38.8
	Total	**170.0**	154.4	**4.9**	**159.3**

Table 2. Usable commercial log records from SFA 29 West from 2002–2013.

Year	Usable Log Records	Total Log Records	% Usable
2002	1551	1768	88
2003	762	824	92
2004	1458	1633	89
2005	835	966	86
2006	1385	1749	79
2007	918	1090	84
2008	919	1079	85
2009	966	1067	91
2010	928	1002	93
2011	1119	1125	99
2012	735	747	98
2013	599	600	100

Table 3. Evaluation of the impact of setting the 2014 catch to be the same as that in 2013 for SFA 29 West. Estimates of exploitation, changes in biomass and probability of decline in biomass were based on assuming that the fishing pattern in 2014 would be the same as in 2013.

Subarea	Habitat Suitability	Catch (t)	Exploitation	% Change in Biomass	Probability of decline
A	Low	0.19	<0.01	16.9	0.39
	Medium	1.11	0.01	-5.4	0.50
B	Low	11.33	0.01	29.2	0.40
	Medium	55.48	0.07	23.2	0.22
	High	20.69	0.24	-0.6	0.51
C	Low	0.87	0.02	-19.5	0.54
	Medium	7.47	0.04	5.6	0.35
	High	9.95	0.13	2.1	0.49
D	Low	0.64	0.03	2.4	0.50
	Medium	21.47	0.09	-2.2	0.55
	High	16.70	0.08	0.8	0.50

Table 4. Estimated total numbers of lobsters caught in the SFA 29 West scallop fishery (Full Bay and East of Baccaro combined) for 2011–2013 based upon observer data. DI (%) refers to the percentage of dead or injured lobsters.

Year	Area	Observer data			Fishery	Estimated	
		No. lobsters	DI (%)	Meats (t)	Meats (t)	No. lobsters	DI
2011	A	24	46	0.5	18.1	867	398
	B	735	33	5.4	59.3	8,065	2,667
	C	1		0.1	45.4	454	0
	D	18	100	6.3	69.8	200	200
	E	188	61	1.1	5.6	959	582
	Total	**966**		**13.4**	**198.1**	**10,545**	**3,845**
2012	A	24	0	0.4	1.0	61	0
	B	164	9	7	78.1	1,830	163
	C	104	49	2	39.8	2,069	1,014
	E	47	2	0.7	18.0	1,207	26
	Total	**339**		**10.4**	**168.9**	**5,168**	**1,203**
2013	A	13	8	0.002	1.3	8,436	649
	B	331	24	7.4	87.5	3,898	954
	C	103	19	2.2	18.3	846	164
	D	50	22	3.2	38.8	606	133
	E	122	24	1.0	13.5	1,598	386
	Total	**619**		**13.9**	**159.3**	**15,385**	**2,286**

NOTE: There were 16 lobsters in 2011 (C – 1, D – 15), 10 lobsters in 2012 (B – 7, C – 3) and 5 lobsters in 2013 (B – 3, E – 2) that were counted but not measured or assessed for condition. A percentage of these are likely dead or injured. These have been included in the No. lobsters above, but assumed alive, without injury.

Table 5. Recent lobster landings (t) by the LFA 34 lobster fishing fleet. Shown are the landings by SFA subarea, for SFA 29 West as a whole, for the area adjacent to SFA 29 West, and LFA 34 as a whole.

Area	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	% Change	
								1 year	5 year
A	366	605	596	586	451	379	355	-5%	-41%
B	1,048	1,265	1,378	1,632	1,464	1,699	1,420	-19%	12%
C	828	840	887	1,008	1,105	1,105	1,005	-9%	20%
D	629	581	494	544	786	945	908	-5%	56%
E	631	658	729	1,095	1,215	1,182	981	-17%	49%
SFA 29W	3,500	3,949	4,083	4,865	5,021	5,308	4,667	-13%	18%
Adjacent	4,716	5,017	5,381	5,681	5,845	6,375	5,781	-10%	15%
LFA 34	16,583	17,145	17,262	19,749	20,401	23,288	22,775	-3%	33%

Table 6. Inshore scallop discard rates for bycatch species in SFA 29 West by year. Discard rates are the weight of discards (kg) observed divided by the weight of scallops (kg, meats) landed during the observed trips.

Species	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
ALLIGATORFISH	0	0	0	<0.001	0	0	0	0.001	0	0	0	0
AMERICAN EEL	0	0	0	0	0	0	0.001	0	0	0	0	0
AMERICAN LOBSTER	0.013	0.038	0.015	0.021	0.066	0.034	0.041	0.052	0.060	0.270	0.039	0.185
AMERICAN PLAICE	<0.001	<0.001	<0.001	0	<0.001	0.001	0.005	0.106		0.002	<0.001	0
ATLANTIC ROCK CRAB	0.057	0.065	0.039	0.028	0.170	0.014	0.192	0.229	0.211	0.444	0.023	0.217
BARNACLES	0	0	0	0	0.002	0	0	0	0	0	0.000	0
BARNDOOR SKATE	<0.001	0	0	0	0	0	0.007	0	0.009	0	0	0.001
BASKET STARS	0.002	0.052	0.048	0	0.001	0	0	0.108	0.002	0.042	0	0
BRITTLE STAR	0.001	0.014	0.691	0	<0.001	0	0.011	0	0	0	0.016	0
CANCER CRAB	0	0	0.001	0	0	0.065	0.061	0	0	0	0	0
CEPHALOPODA C.	0	0	<0.001	0	0	0	0	0.016	0	0	0	0
CLAMS	<0.001	0.023	0.249	0.124	0.007	0	0.008	0	0.000	0.429	0	0.084
COD (ATLANTIC)	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001	<0.001	0.002	0	<0.001
COMMON MUSSELS	0.034	0.073	0.112	0.173	0.263	0.017	0.242	0.148	0.001	0.689	1.459	0.142
CORALS	0	0	0	0	0.001	0	0	0	0	0	0	0
CUSK	0	<0.001	0	0	0	0	0	0	0	0	0	0
HADDOCK	<0.001	0	0	0	<0.001	0	0	0	<0.001	0	0	0
HALIBUT (ATLANTIC)	0	<0.001	<0.001	0	0	0	0.004	0	0	0	0	<0.001
HERMIT CRABS	0.018	0.015	0.019	0.014	0.019	0.131	0.052	0.091	0.030	0.109	0.012	0.063
HYDROZOA C.	<0.001	0	0	0	0	0	0	0	0	0	0	0
ICELAND SCALLOP	<0.001	<0.001	<0.001	0	0.002	0	0	0	0.001	0	0	0
JELLYFISHES	<0.001	<0.001	0	0	0	0	0	0	0	0	0	<0.001
JONAH CRAB	0.031	0.215	0.069	0.070	0.124	0.246	0.151	0.188	0.012	0.829	0.148	0.133
LEMONWEED	<0.001	0.010	0	<0.001	0.002	0	0	0	0.001	0	0	0
LITTLE,WINTER SKATE	0.006	0.007	0	0.018	0.015	0.001	0.074	0.071	0.047	0.140	0.025	0.046
LONGHORN SCULPIN	0.016	0.022	0.020	0.027	0.023	0.024	0.168	0.071	0.072	0.116	0.019	0.001
LUMPFISH	0	0	0	<0.001	<0.001	0	0.003	0.016	0	0	0	0
MONKFISH	0.025	0.010	0.009	0.008	0.006	0.003	0.019	0.036	0.004	0.019	0.003	0.003
MULLET FISH	0.001	0	0	0	0	0	0	0	0	0	0	0
NORTHERN STONE CRAB	0	0	0	0	0	0.020	0.013	0	0	0	0	0
OCEAN POUT	<0.001	<0.001	<0.001	0	<0.001	0	0	0.001	0	0.001	0	0
OCEAN QUAHAUG	0	0	0	<0.001	0	0	0	0	0	0	0	0
OCTOPUS	0	0	0	0	0	0	0	0.001	0	0	0	0
POLLOCK	<0.001	0	0	0	0	0	0	0	0	0	0	0
PRICKLEBACKS	0	0	0	0	<0.001	0	0	0	0	0	0	0
REDFISH UNSEPARATED	0	0	<0.001	0	<0.001	0	0	0	<0.001	0	0	0
ROUND SKATE	0	0.001	0	<0.001	0.004	0	0	0	0.001	0	0	0
SAND DOLLARS, SEA URCHINS	0.033	0.017	0.018	0.043	0.058	0.108	0.045	0.119	0.058	<0.001	0.001	0.030
SAND LANCES	0	<0.001	0	0	0	0	0	0	0	0	0	0
SEA ANEMONE	<0.001	0	0	0	<0.001	0	0	0	<0.001	0	0	0
SEA CUCUMBERS	0.035	0.005	0.030	0.455	0.434	0.097	0.614	0.271	0.054	0.025	0.055	0.360
SEA LAMPREY	0	0	<0.001	0	0	0	0	0	0	0	0	0
SEA PEACH	0	0	0	0	0.001	0	0	0	0	0	0	0
SEA POTATO	0	0	0	0	<0.001	0	0	0	0	0	0	0
SEA RAVEN	0.019	0.025	0.025	0.024	0.062	0.017	0.053	0.058	0.064	0.221	0.029	0.050
SEA SCALLOP	0.273	0.675	0.876	1.140	0.550	0.589	0.527	0.923	1.131	2.998	0.394	1.203
SEAROBINS	<0.001	0	0	0	0	0	0	0	0	0	0	0
SHORTHORN SCULPIN	0	0	0	0	<0.001	0	0.002	0	0	0.001	0	0
SHRIMP	0	0.001	0	<0.001	<0.001	0	0	0	0	0	<0.001	0
SILVER HAKE	0	0	0	0	0	0	0.001	0	0	0	<0.001	0
SMOOTH SKATE	0.006	<0.001	0.002	0.003	<0.001	0	0.024	0.063	0	0	<0.001	0
SNAILS AND SLUGS	<0.001	0	0.001	0.005	0.002	0	0	0.040	0.006	0	<0.001	0
SPONGES	0.089	0.047	0.739	0.126	0.019	0	0.212	0.266	0.058	0.052	0.009	0.004
STARFISH	0.180	0.091	0.129	0.285	0.353	0.279	0.823	0.575	0.092	0.486	0.010	0.058
STRIPED ATLANTIC WOLFFISH	0	0	0.001	<0.001	<0.001	0	0.001	0	0.005	0	0.001	<0.001
THORNY SKATE	0.001	0.012	0.011	0.003	0.013	0.036	0.069	0.055	0.017	0.013	0.004	0.029
TOAD CRAB	0.022	0	<0.001	0	0.001	0	0.012	0	0	0.001	0	<0.001
TUNICATE	0	0	0	0	<0.001	0	0.002	0	<0.001	0	0	0
UNIDENT BIVALVES	<0.001	0.004	0	0	0	0	0	0	0	0	0	0
UNIDENT FLOUNDER	0	0	<0.001	0	0	0	0	0	0	0	0	0
UNIDENT SCULPINS	0.001	0.003	0.006	0.006	0.001	0.011	0	0	0	0.003	<0.001	0.064
UNIDENT SKATES	0.006	0.010	0.009	0.004	<0.001	0	0.087	0.058	0	0	0	0
WHELKS	0	0	0.001	0	0.002	0	0	0.022	<0.001	0	0	0.025
WHITE HAKE	<0.001	0	0	0	0	0	0	0.004	0	0	<0.001	0
WINTER FLOUNDER	0.002	0.002	0.004	0.003	0.003	0.003	0.017	0.015	0.040	0.063	0	0.064
WITCH FLOUNDER	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	0.004	0.002	0.007	0.009	0.003
YELLOWTAIL FLOUNDER	0.001	<0.001	0.001	<0.001	0.001	0.001	0.009	0.006	0.002	0	<0.001	<0.001

FIGURES

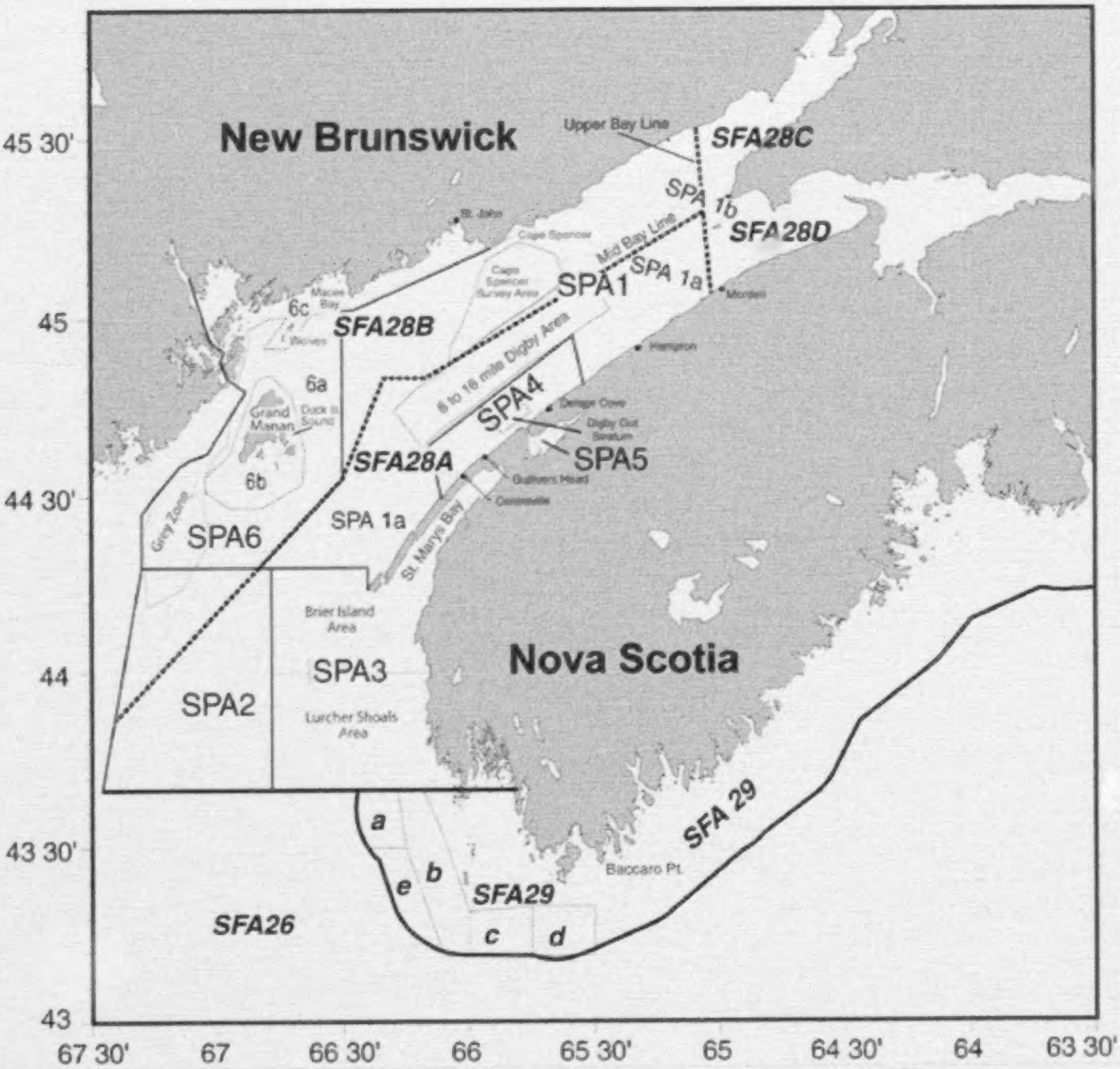

Figure 1. Map of Inshore Scallop Fishing Areas (SFAs) and Scallop Production Areas (SPAs).

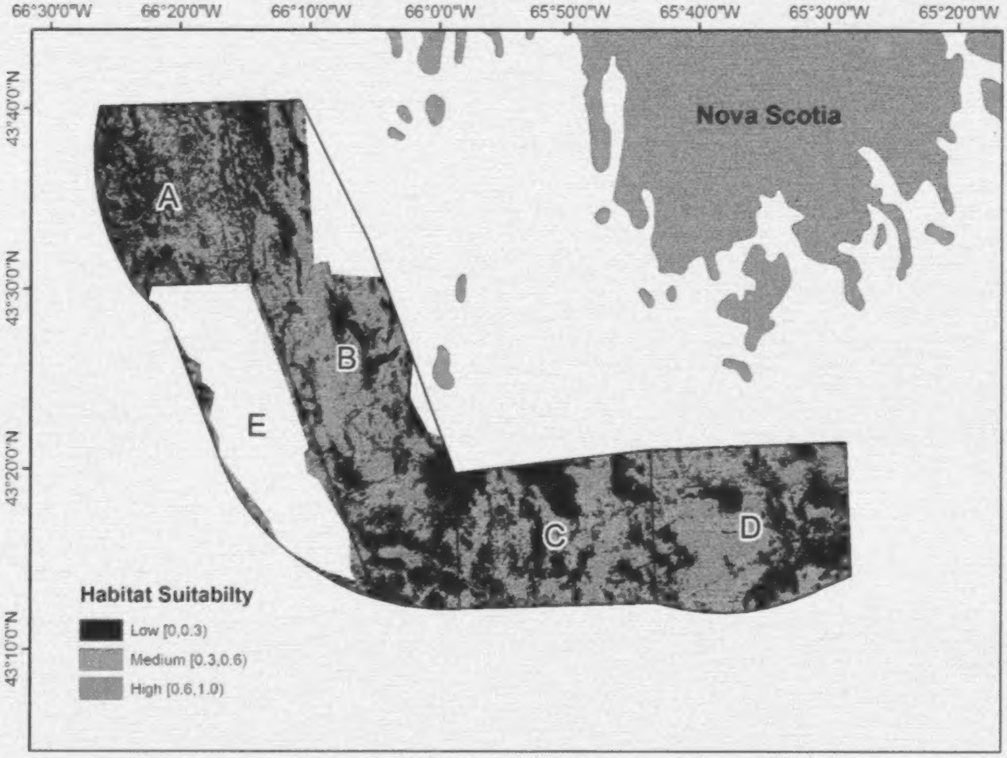

Figure 2. Scallop habitat suitability map from the Maxent Species Distribution Model binned by Low [0, 0.3), Medium [0.3, 0.6), and High [0.6, 1.0) categories of habitat suitability probabilities for SFA 29 West. (Original habitat suitability map can be found in Brown et al. (2012)).

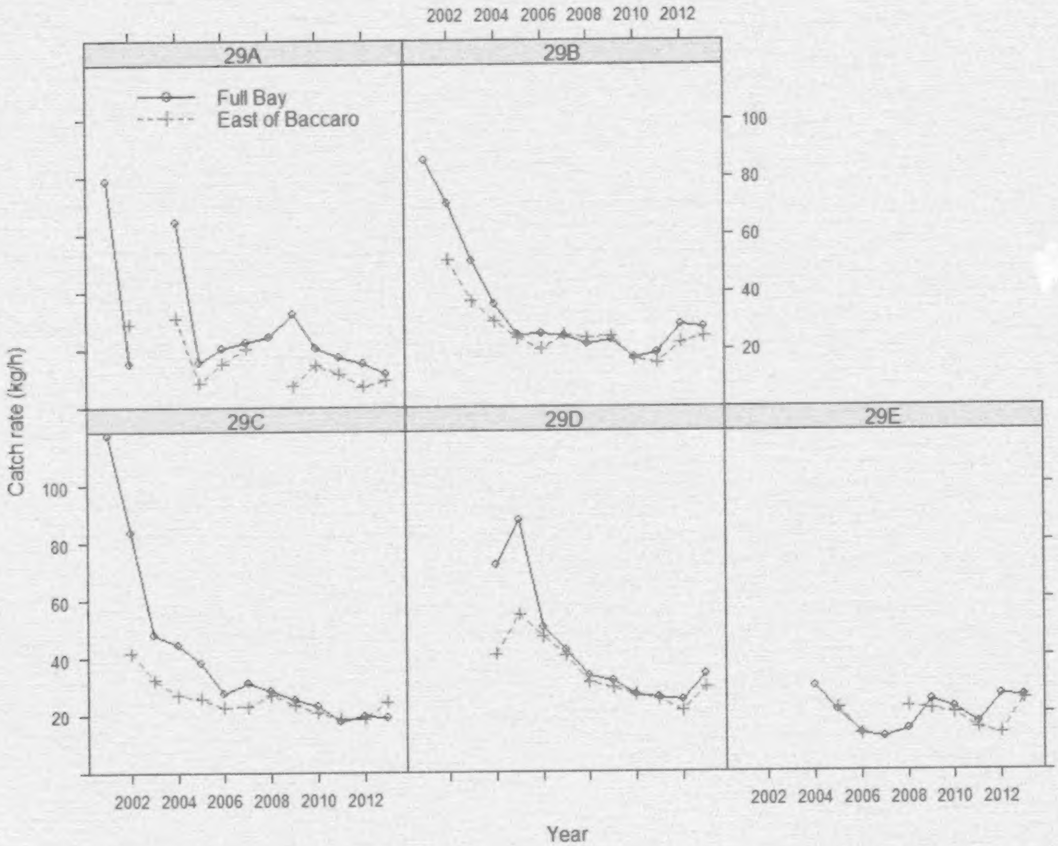

Figure 3. Annual trends for average commercial catch rate (kg/h) for SFA 29 West scallop fishery for each subarea by fleet (Full Bay and East of Baccaro) from logbook data from 2001 to 2013.

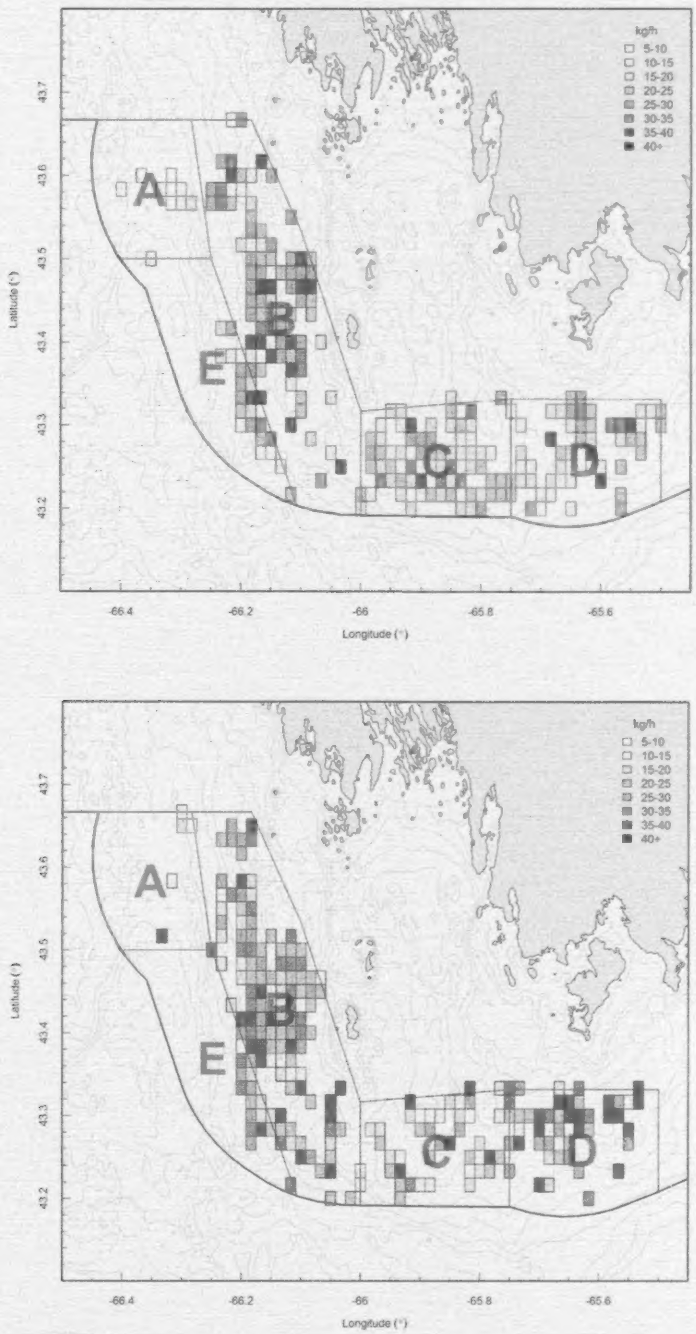

Figure 4. Catch per unit effort (kg/h) for the fishery in SFA 29 West. Locations obtained from fishing logs in 2012 (top) and 2013 (bottom).

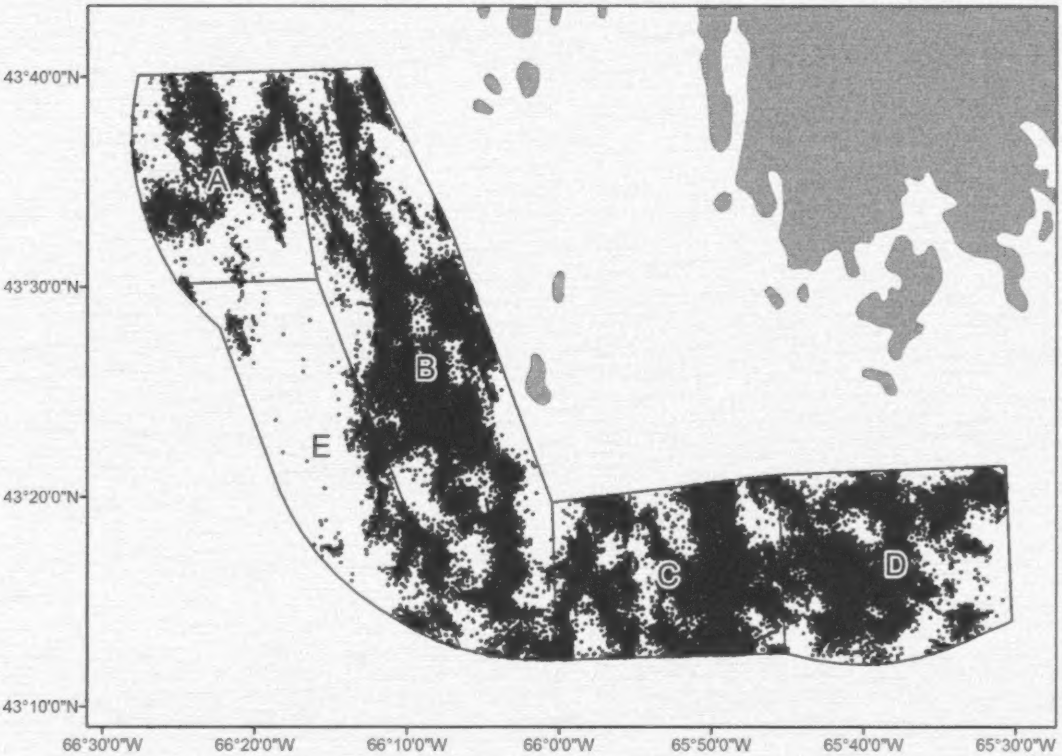

Figure 5. VMS locations filtered on speed to identify fishing from 2002 to 2013 in SFA 29 West.

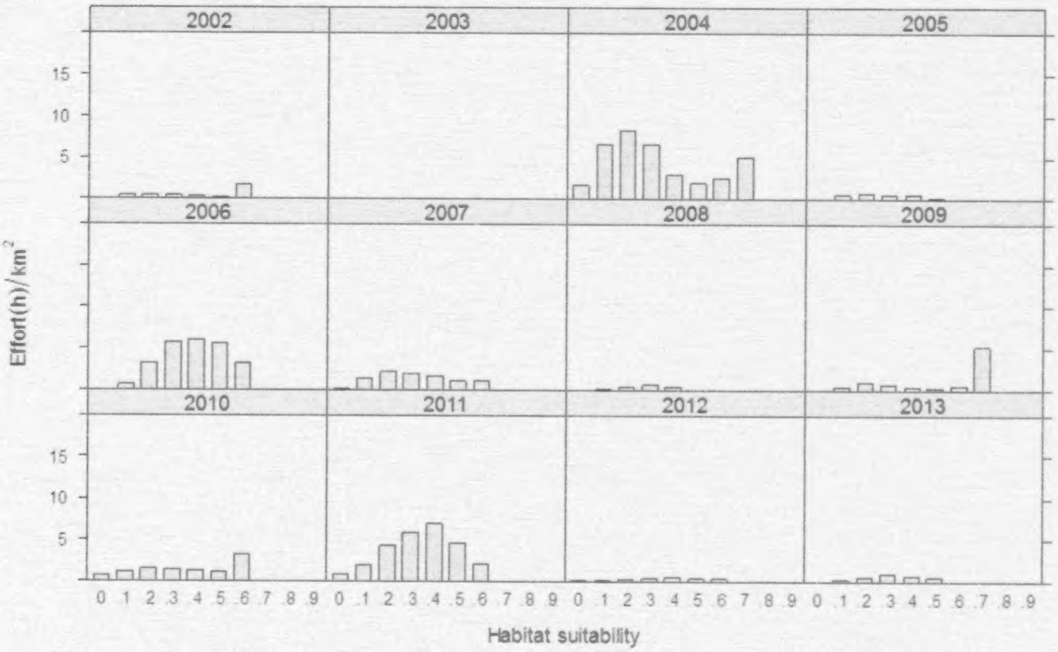

Figure 6. Fishing effort/km² derived from VMS data binned by 0.1 categories of habitat suitability probabilities for SFA 29A from 2002 to 2013. There were no suitability bins ≥ 0.8 in this subarea.

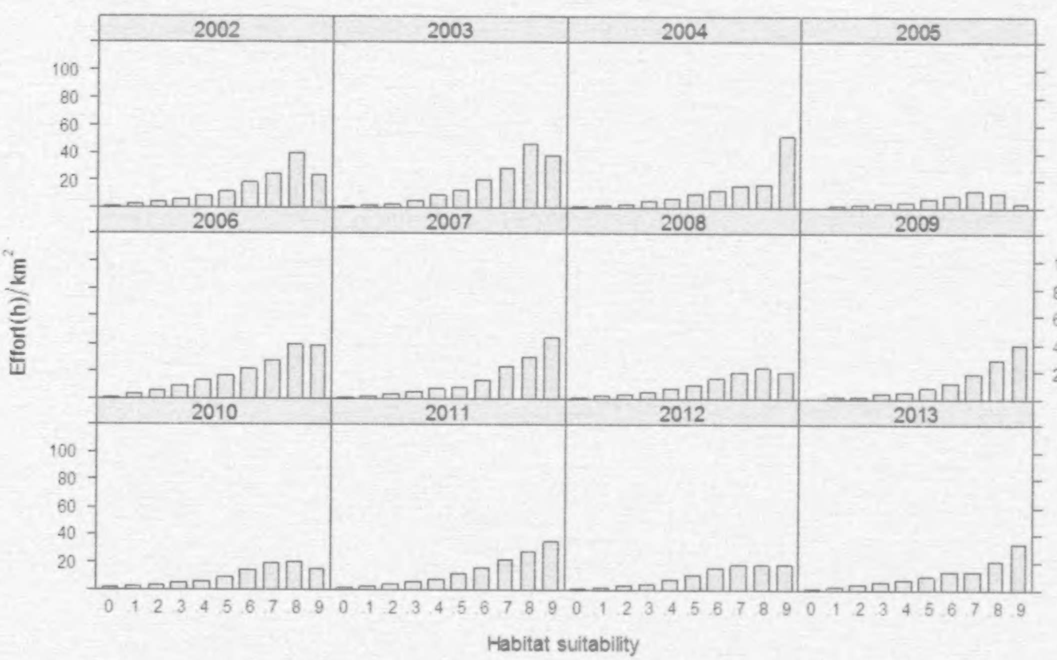

Figure 7. Fishing effort/km² derived from VMS data binned by 0.1 categories of habitat suitability probabilities for SFA 29B from 2002 to 2013.

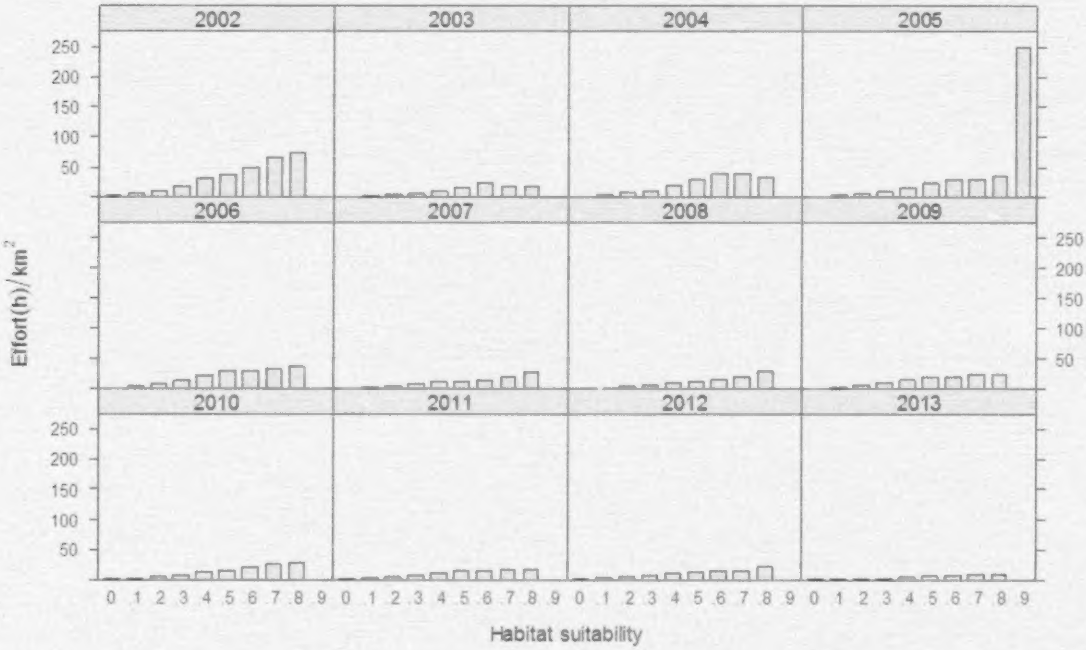

Figure 8. Fishing effort/km^2 derived from VMS data binned by 0.1 categories of habitat suitability probabilities for SFA 29C from 2002 to 2013.

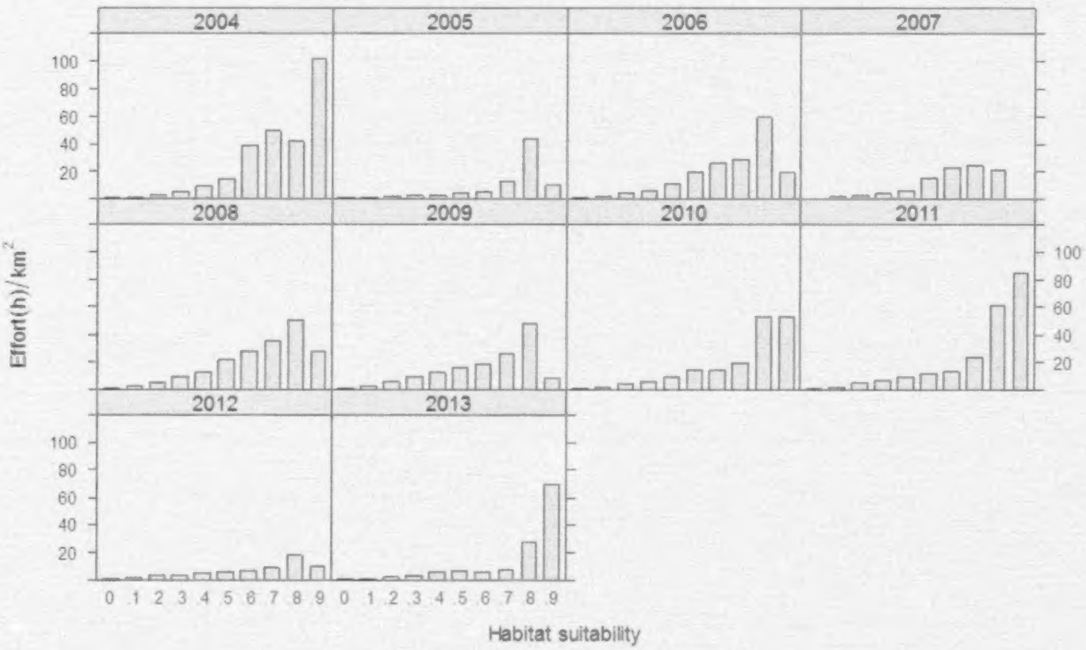

Figure 9. Fishing effort/km^2 derived from VMS data binned by 0.1 categories of habitat suitability probabilities for SFA 29D from 2004 to 2013.

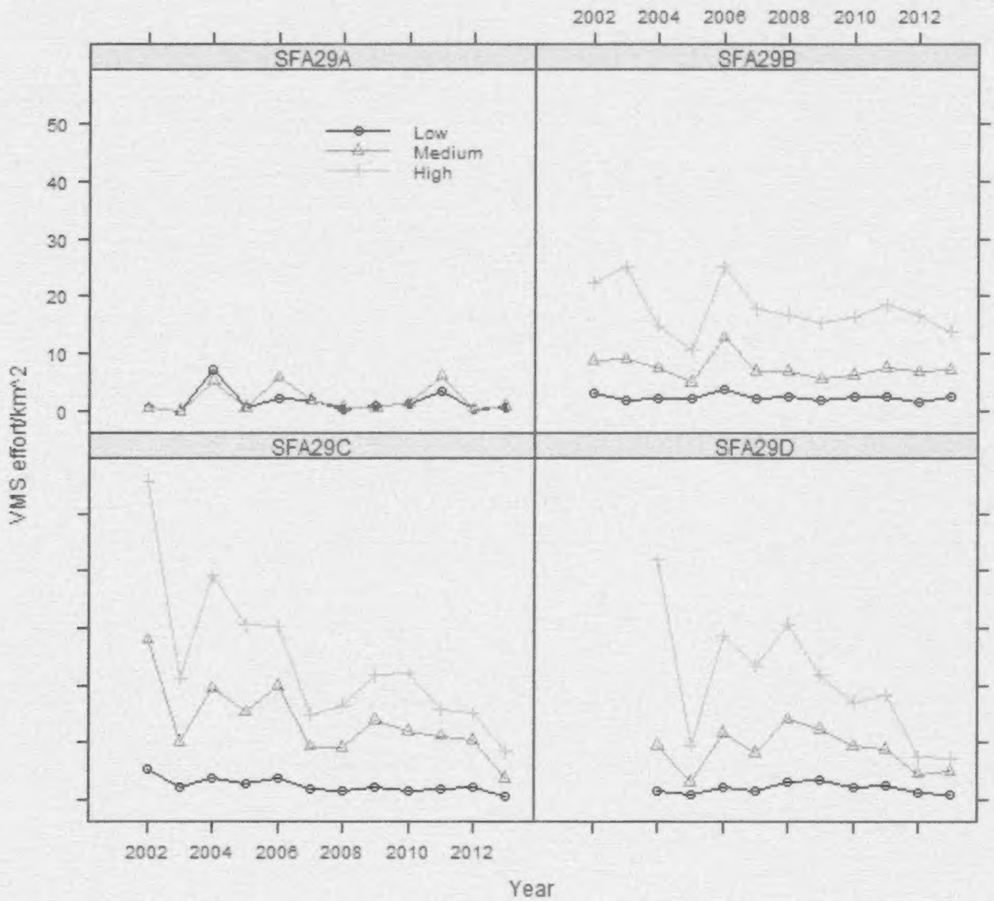

Figure 10. Fishing effort/km^2 derived from VMS data binned by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities for SFA 29 West from 2002 to 2013.

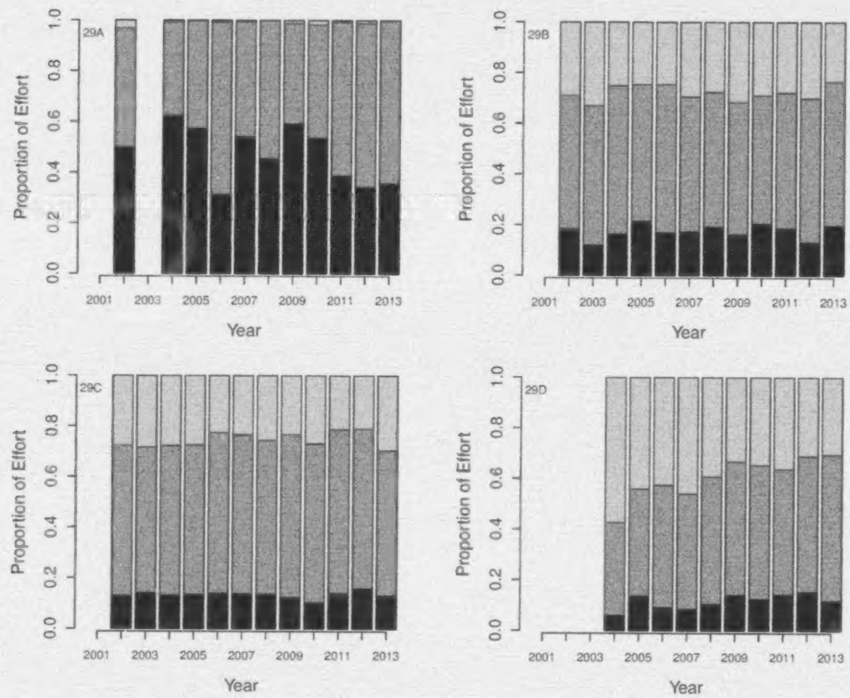

Figure 11. Proportion of effort by year based on VMS data by Low ([0, 0.3), black), Medium ([0.3, 0.6), red), and High ([0.6, 1.0), green) categories of habitat suitability probabilities for SFA 29 West from 2002 to 2013.

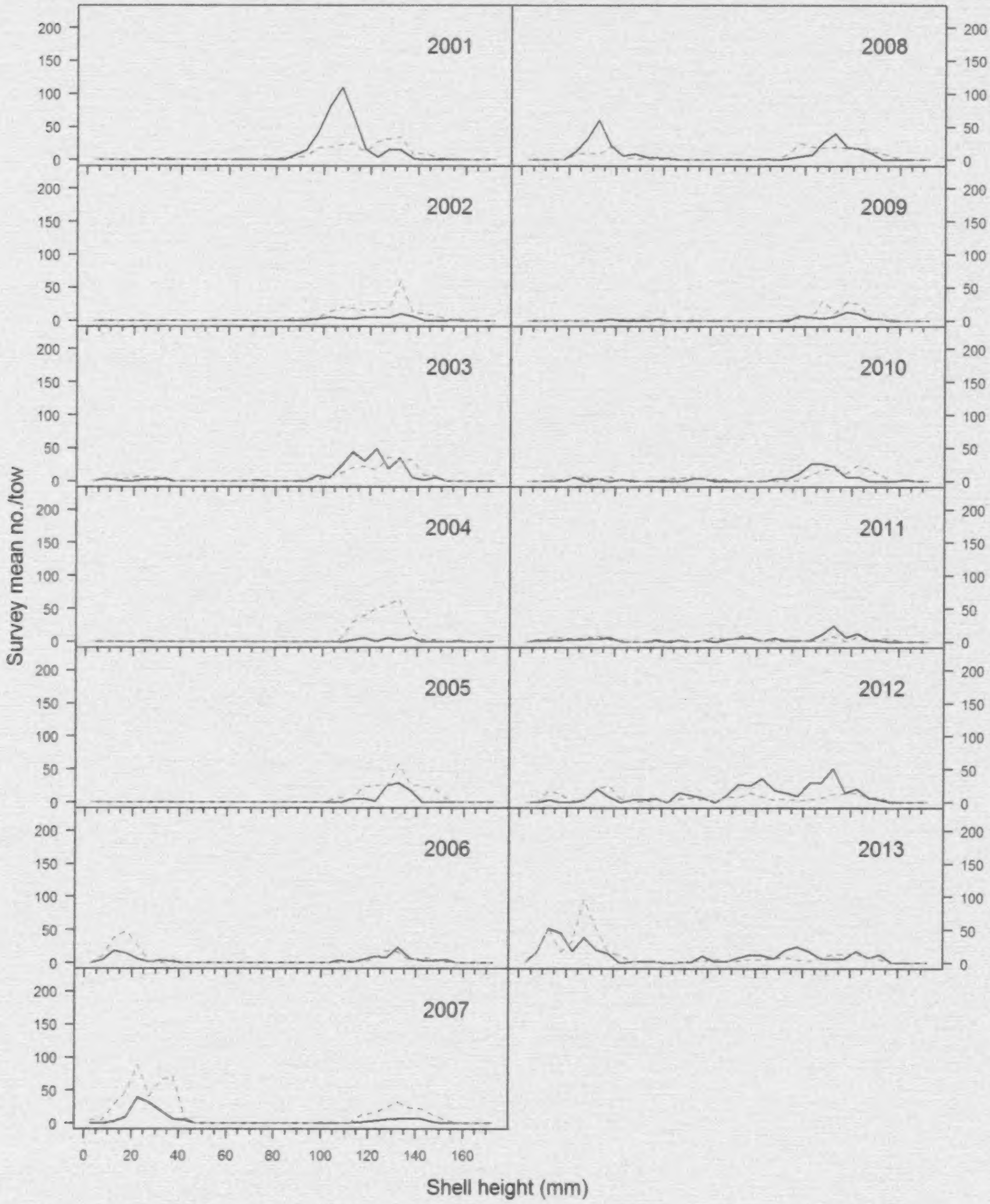

Figure 12. SFA 29A scallop shell height (mm) frequencies (mean number/tow) from the surveys binned by Low ([0, 0.3), black), Medium ([0.3, 0.6), red), and High ([0.6, 1.0), green) categories of habitat suitability probabilities from 2001 to 2013.

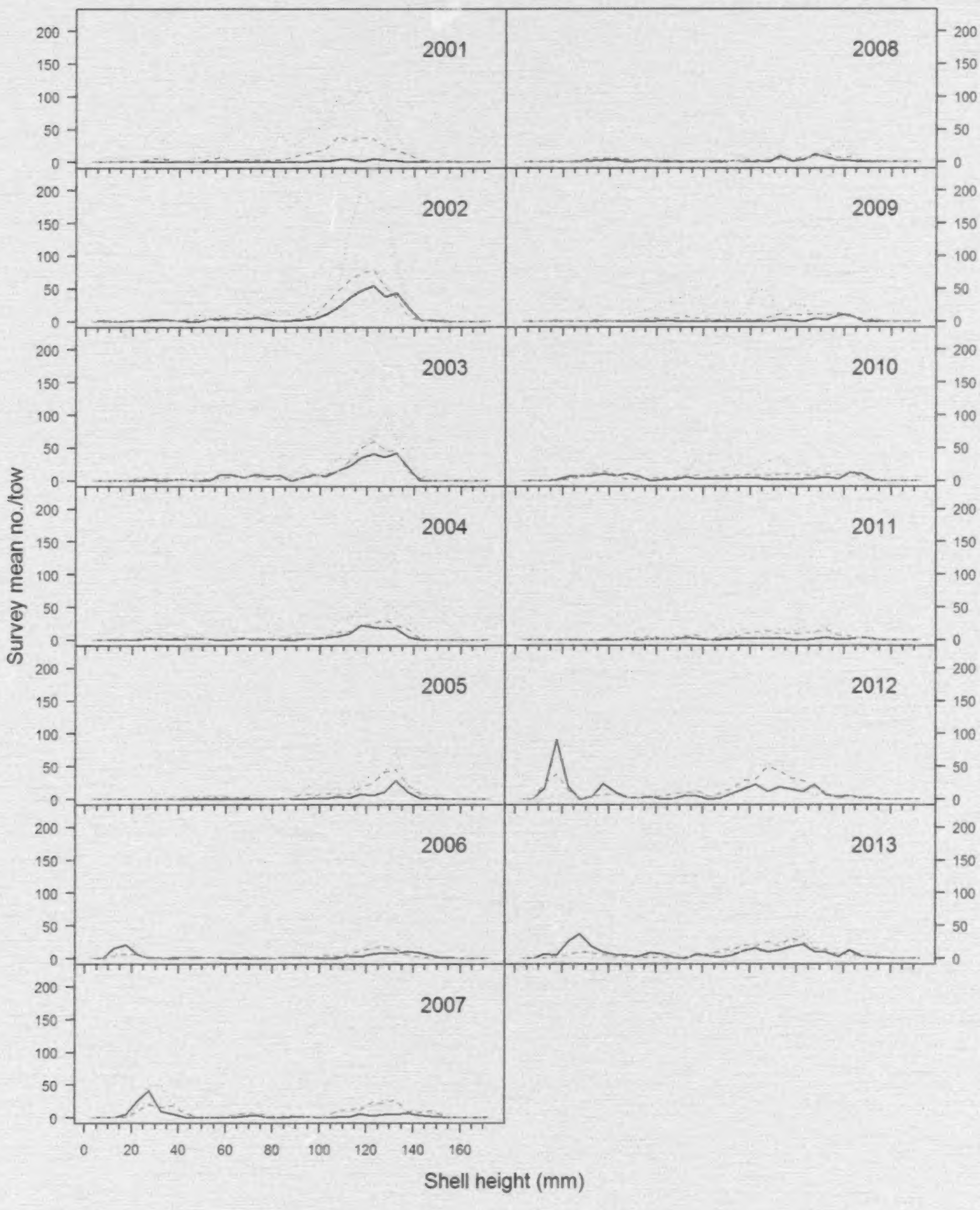

Figure 13. SFA 29B scallop shell height frequencies (mean number/tow) from the surveys binned by Low ([0, 0.3), black), Medium ([0.3, 0.6), red), and High ([0.6, 1.0), green) categories of habitat suitability probabilities from 2001 to 2013.

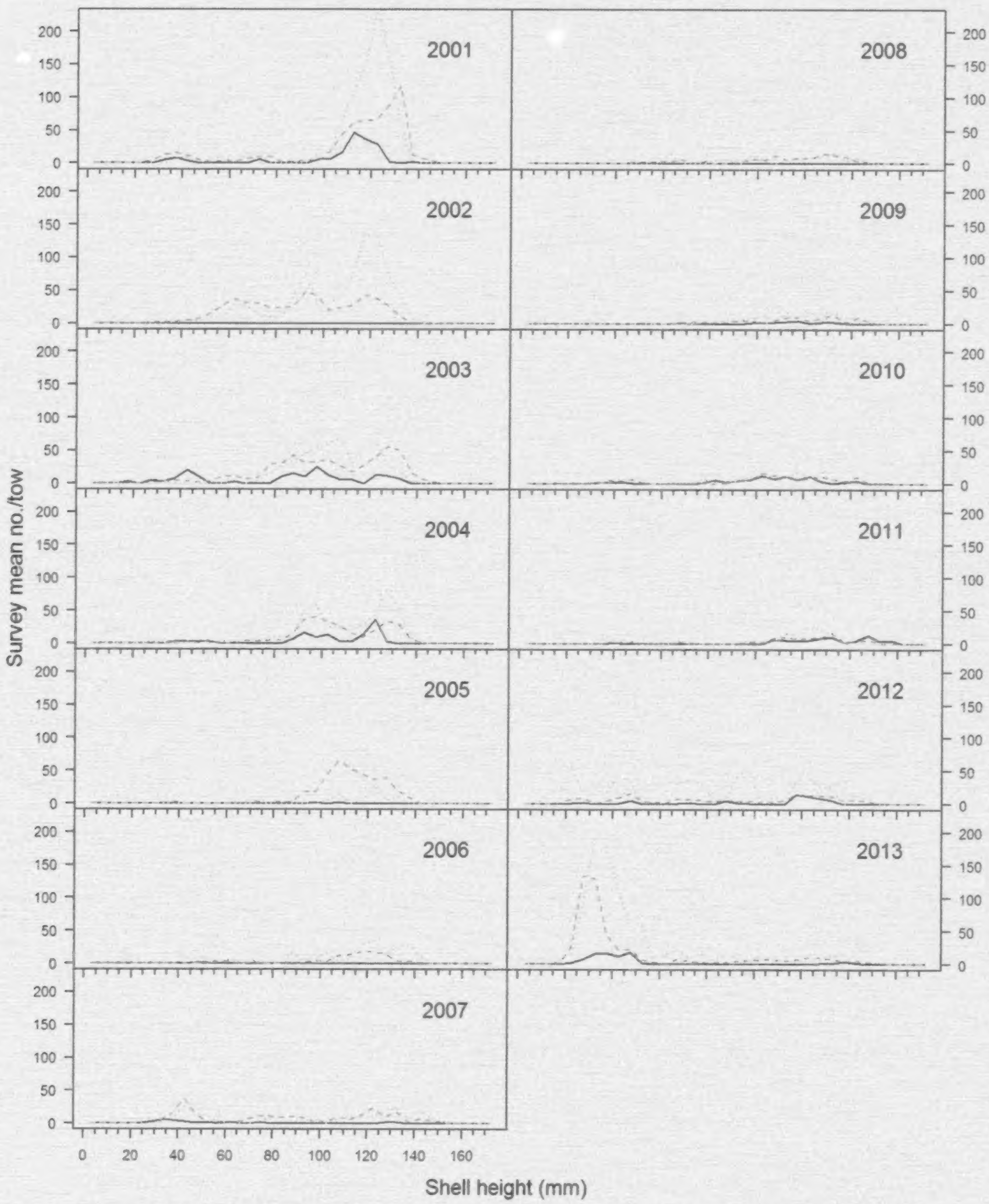

Figure 14. SFA 29C scallop shell height frequencies (mean number/tow) from the surveys binned by Low ([0, 0.3), black), Medium ([0.3, 0.6), red), and High ([0.6, 1.0), green) categories of habitat suitability probabilities from 2001 to 2013.

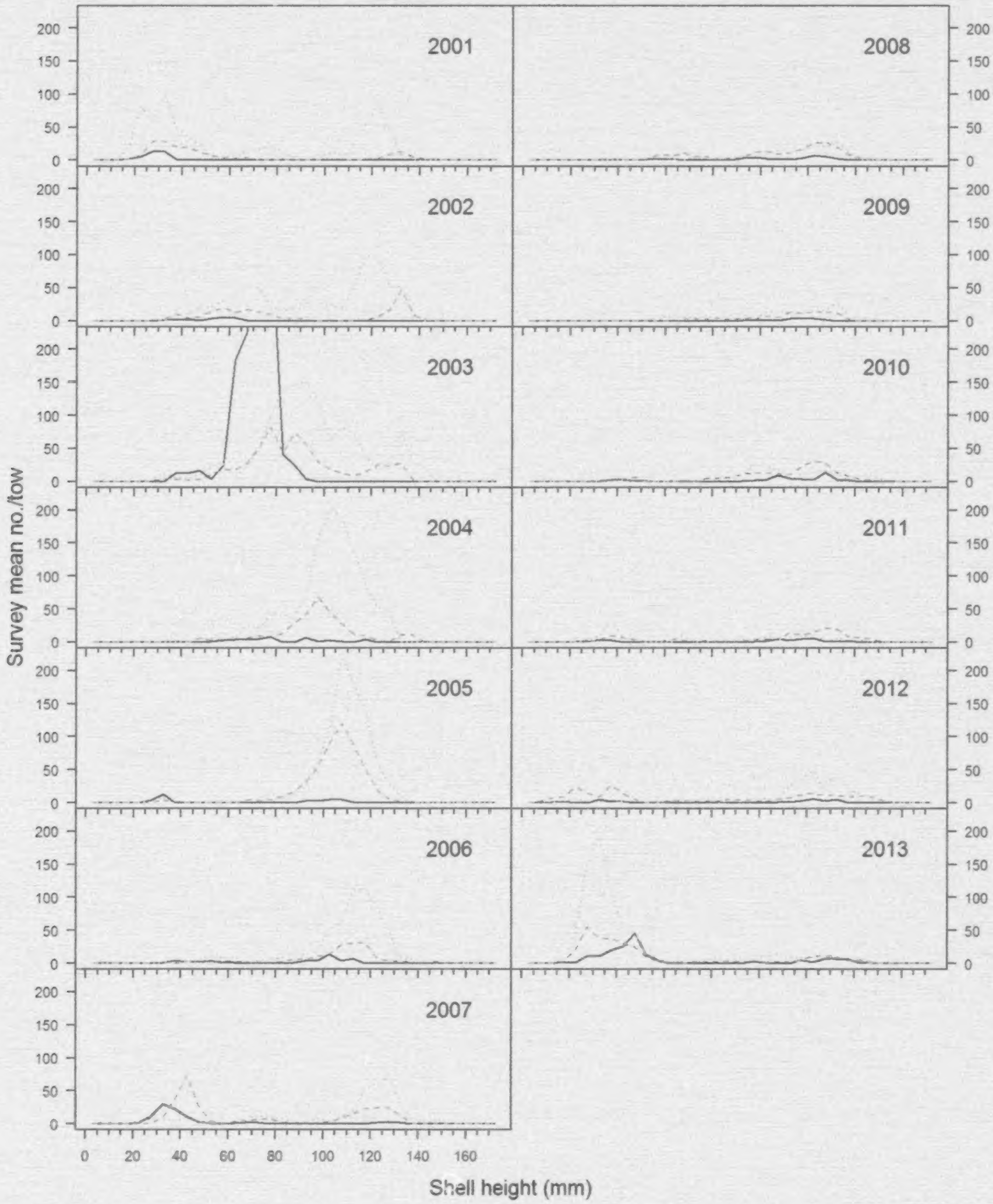

Figure 15. SFA 29D scallop shell height frequencies (mean number/tow) from the surveys binned by Low ([0, 0.3), black), Medium ([0.3, 0.6), red), and High ([0.6, 1.0), green) categories of habitat suitability probabilities from 2001 to 2013.

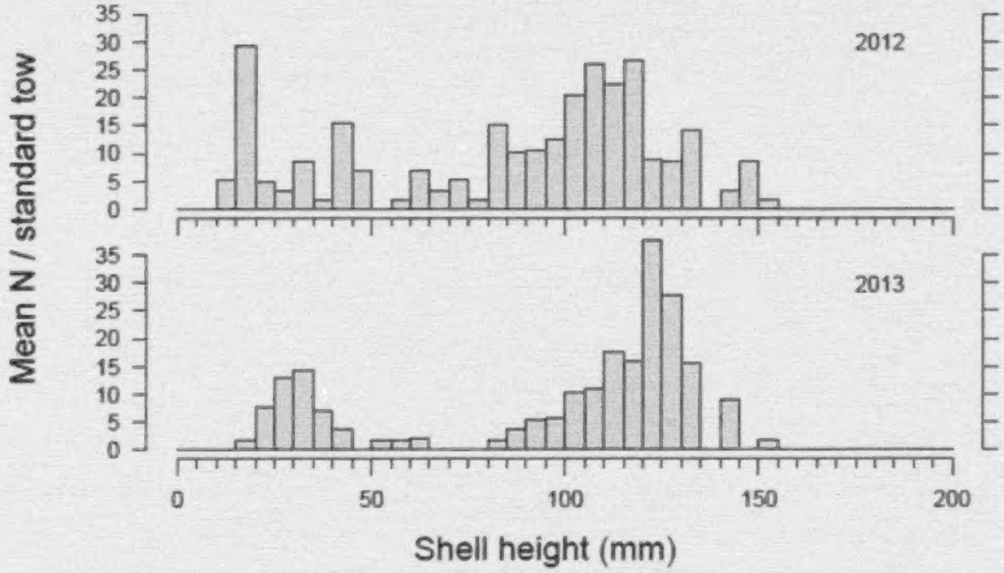

Figure 16. SFA 29E scallop shell height frequencies (mean number/tow) from the survey in 2012 and 2013. Estimates based on 5 exploratory tows.

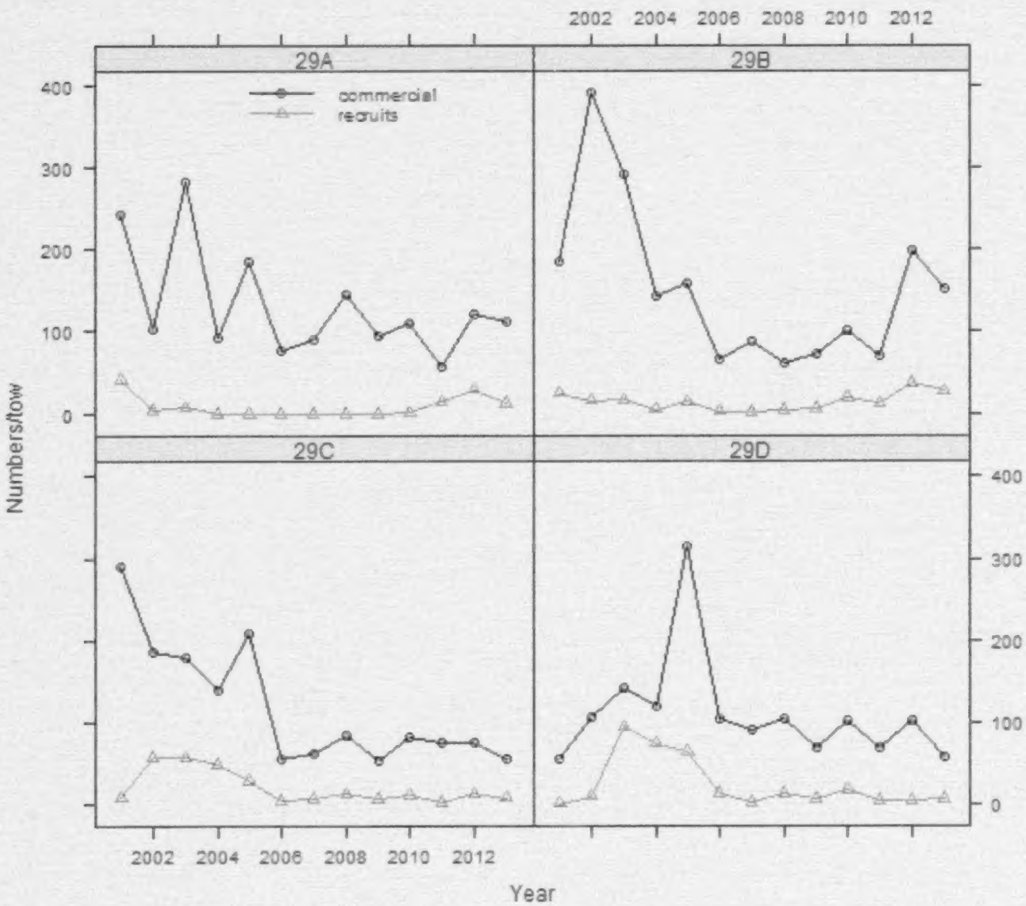

Figure 17. Annual trends in estimated mean number per tow of commercial (≥ 100 mm shell height) and recruit (90–99 mm shell height) size classes from research surveys by subarea in SFA 29 West from 2001 to 2013. Geophysical strata were used for survey design.

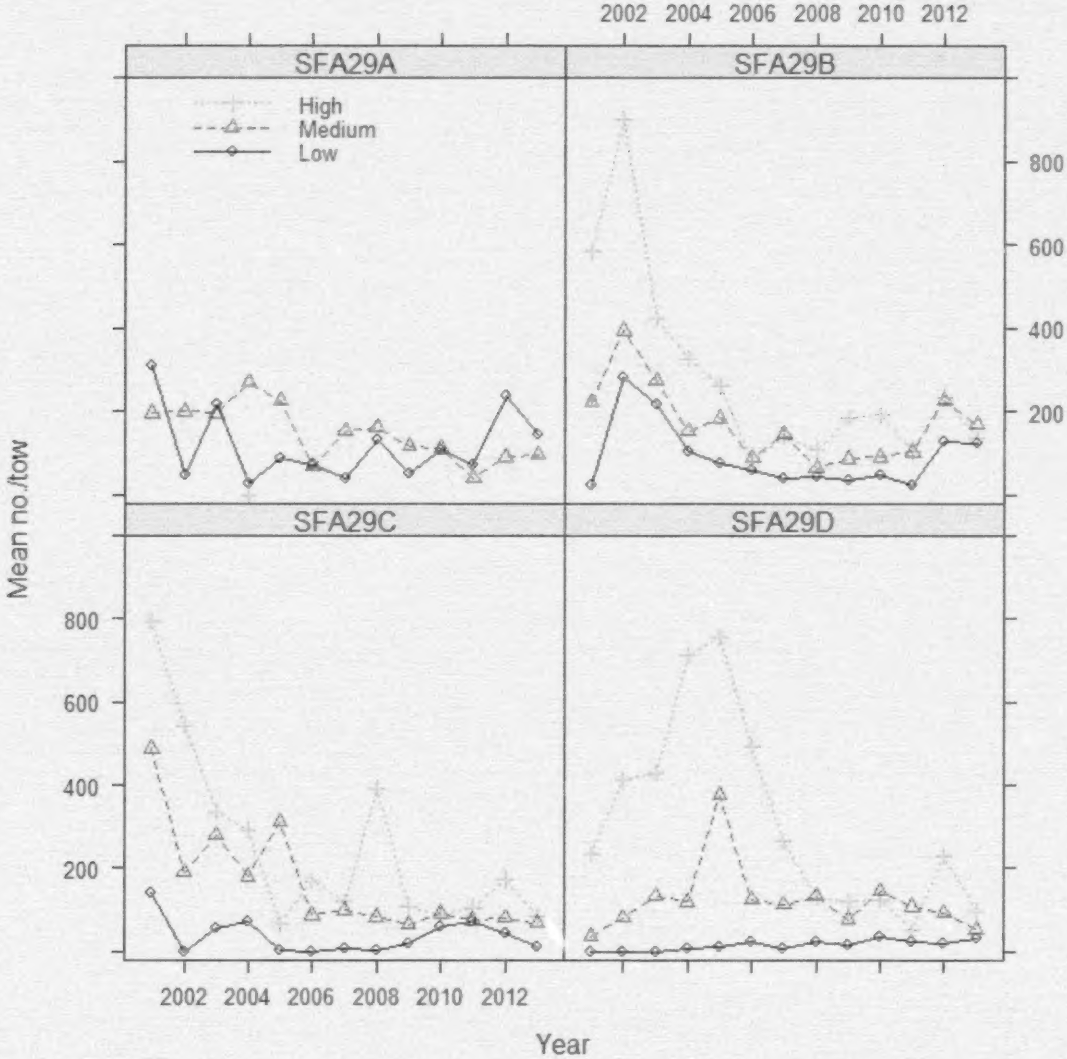

Figure 18. Survey mean number per tow for commercial size scallops (≥ 100 mm) by subarea for SFA 29 West from 2001 to 2013 for Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities. Mean coefficients of variation (CVs) over the time series ranged from 0.24 to 0.75.

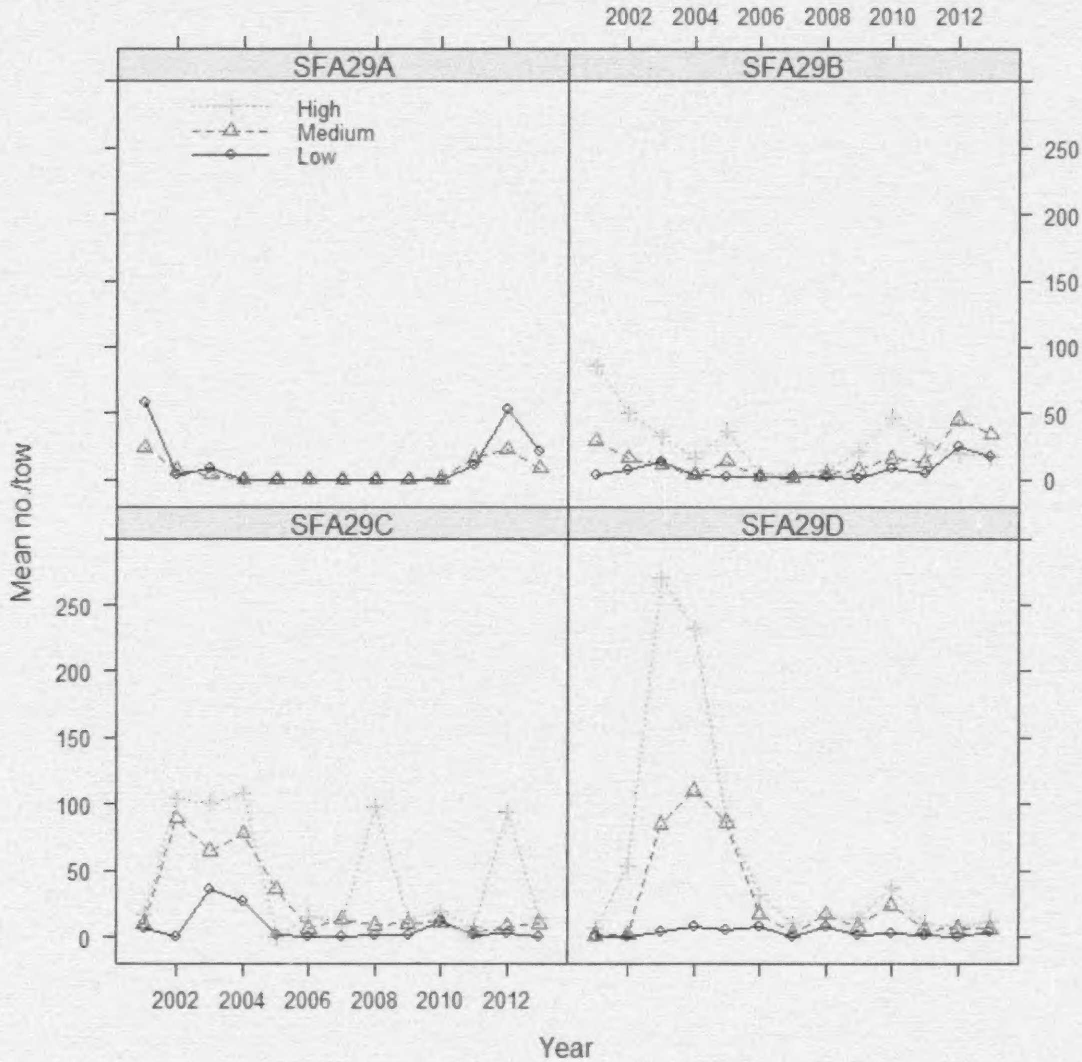

Figure 19. Survey mean number per tow for recruit size scallops (90–99 mm) by subarea for SFA 29 West from 2001 to 2013 for Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities. Mean CVs over the time series ranged from 0.43 to 0.94.

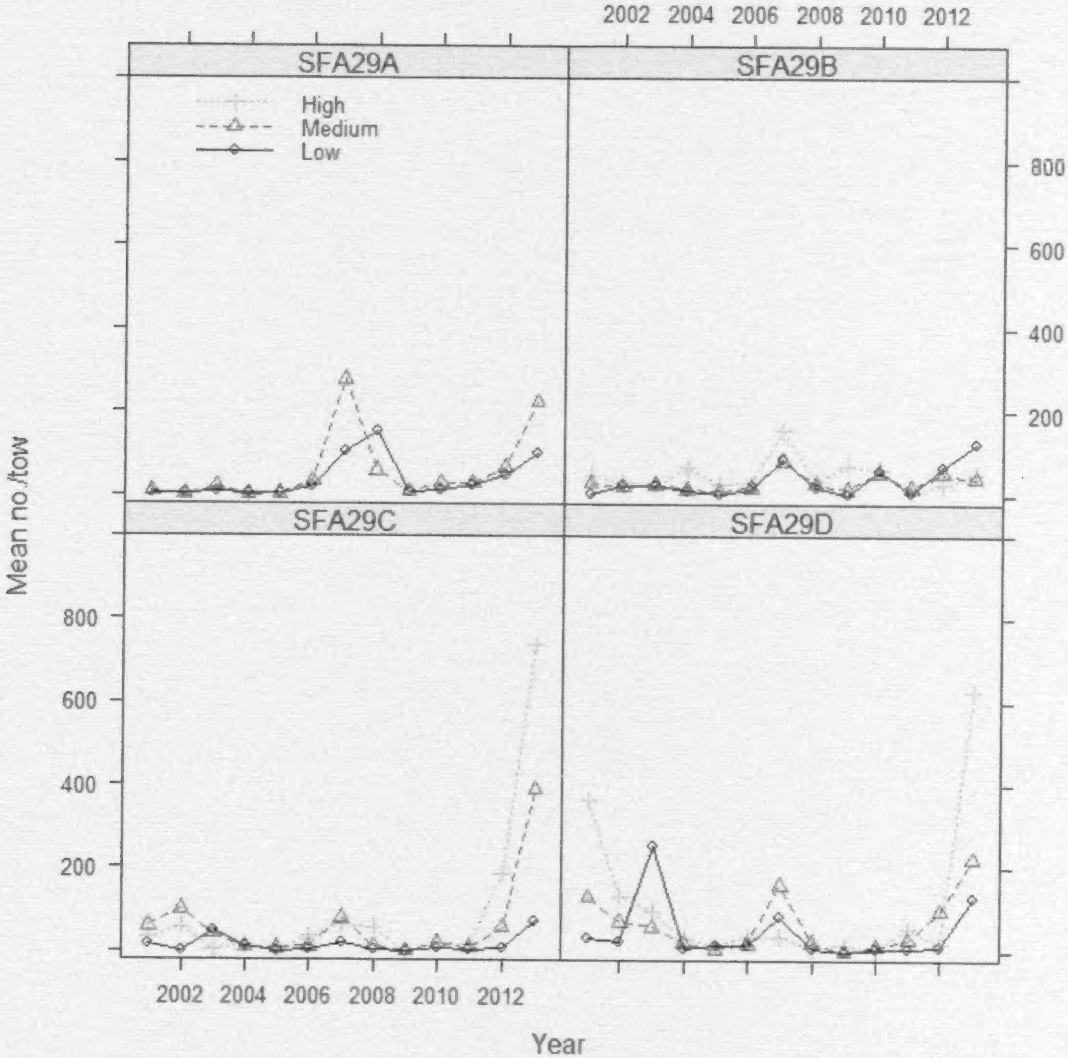

Figure 20. Survey mean number per tow for pre-recruit size scallops (20–60 mm) by subarea for SFA 29 West from 2001 to 2013 for Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities. Mean CVs over the time series ranged from 0.2 to 1.2.

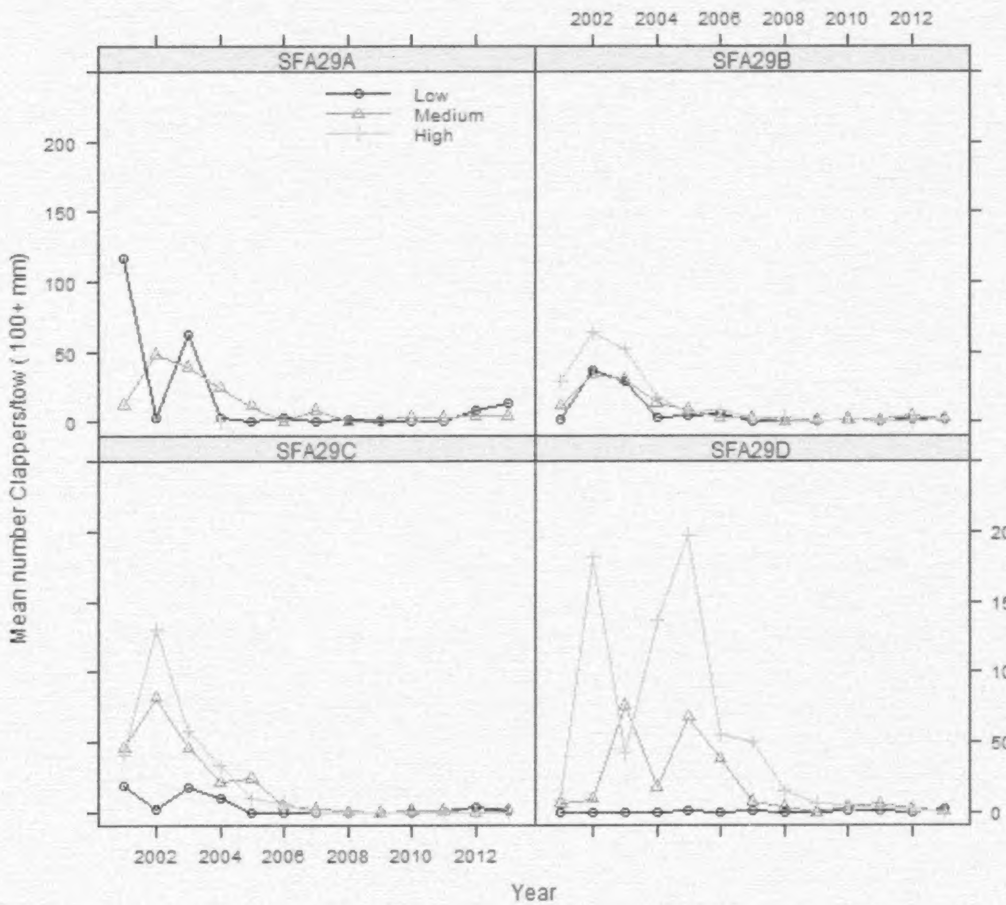

Figure 21. Survey mean number per tow for commercial sized clappers (≥ 100 mm) by subarea for SFA 29 West from 2001 to 2013 for Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities.

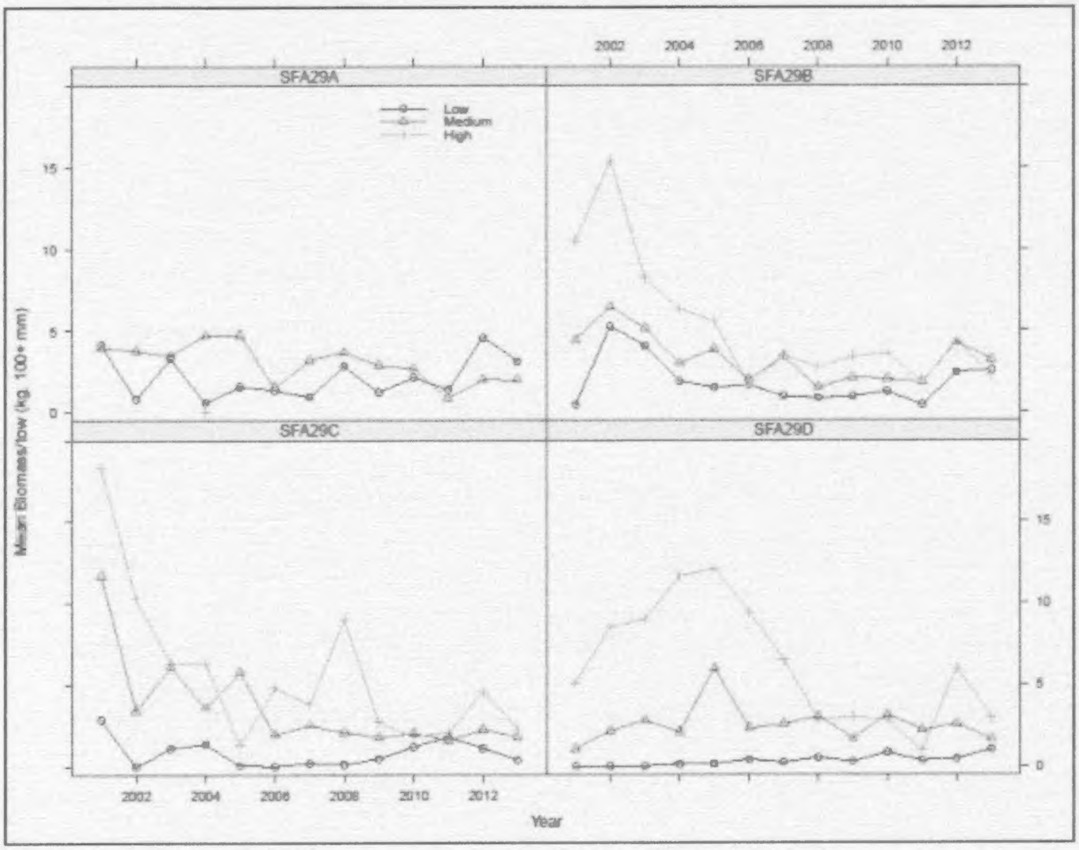

Figure 22. Survey mean weight per tow (meats, kg) for commercial size scallops (≥ 100 mm) by subarea for SFA 29 West from 2001 to 2013 for Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities.

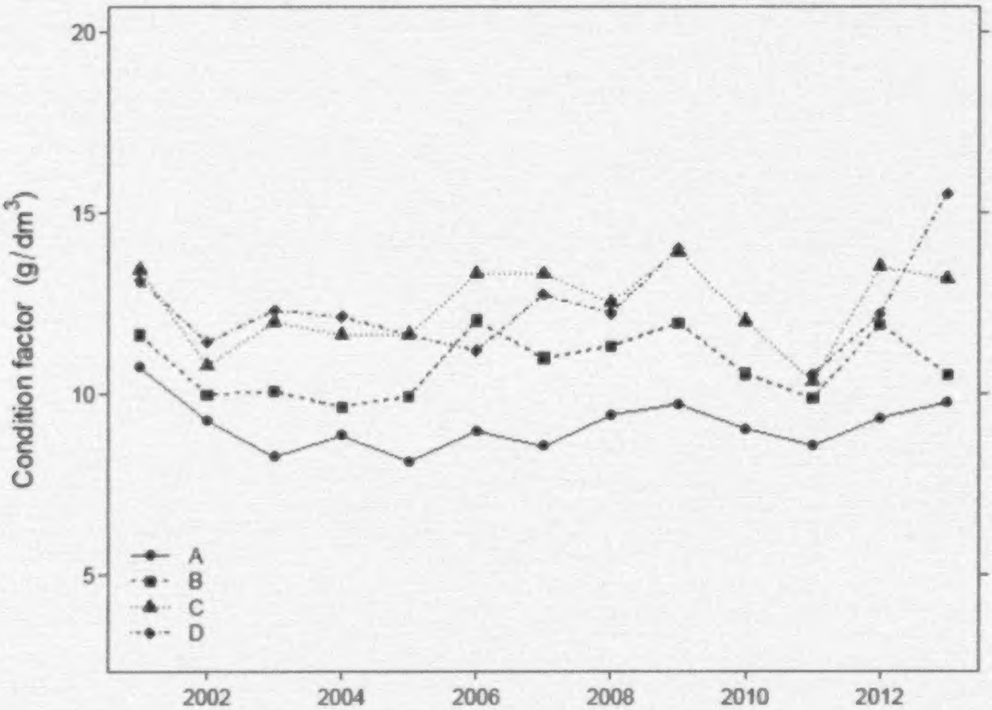

Figure 23. Annual trend in condition factor (g/dm^3 (grams per decimeter cubed)) for scallops from the annual surveys of SFA 29 West from 2001 to 2013 by subareas A to D.

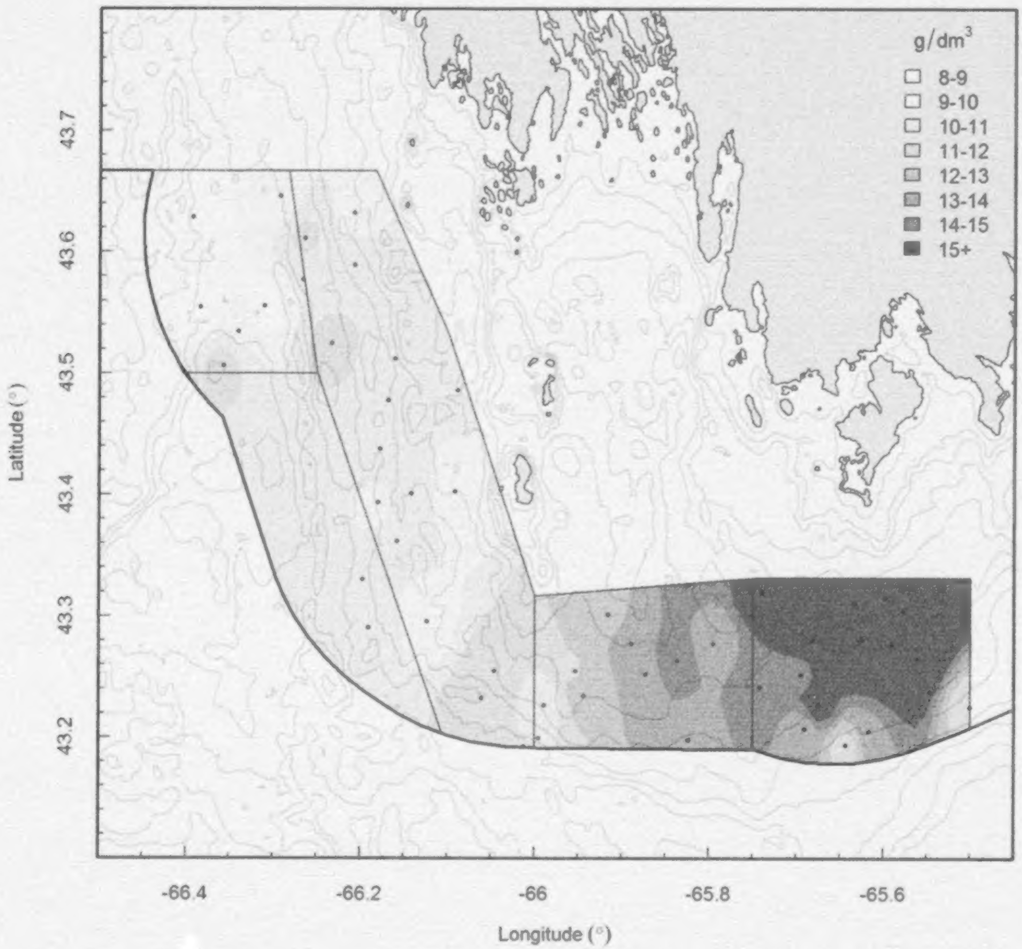

Figure 24. Spatial distribution of condition factor (g/dm3) from the 2013 survey data for SFA 29 West. Points represent sampled tow locations.

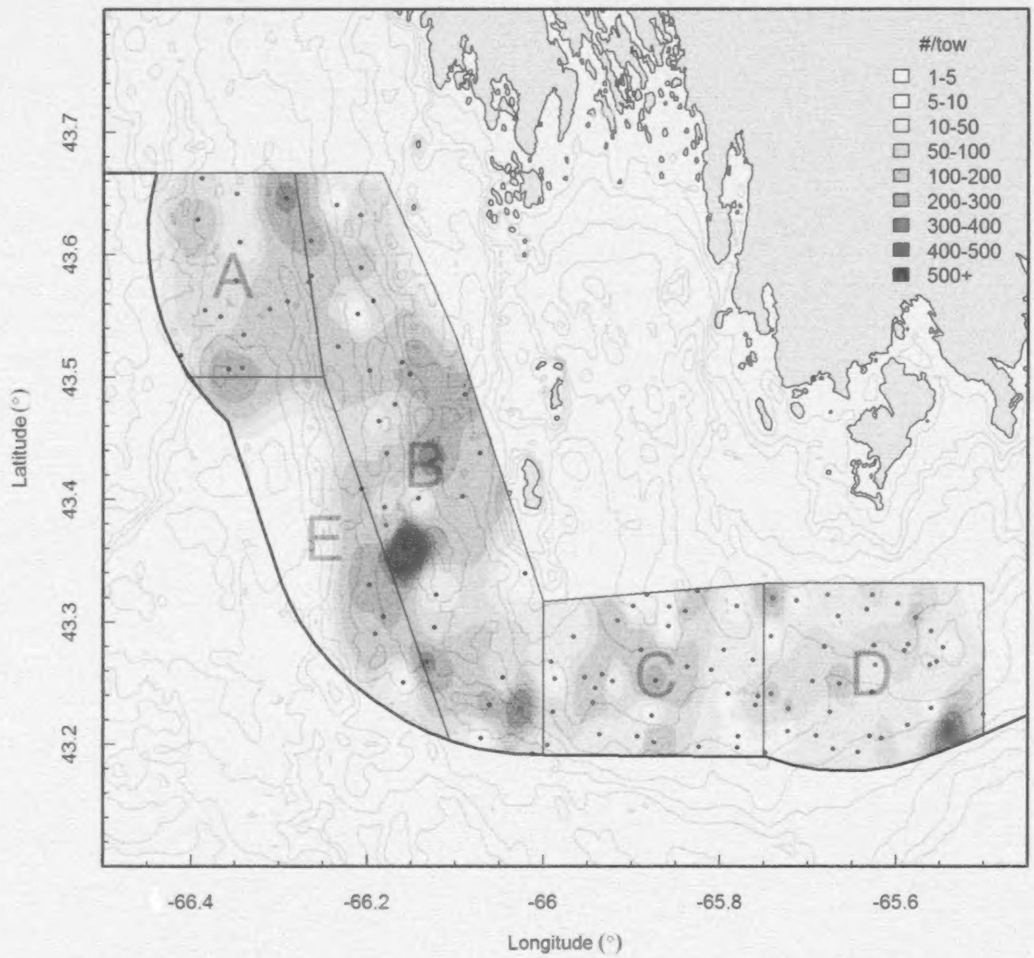

Figure 25. Spatial density (numbers/tow) distribution of commercial scallops (≥ 100 mm shell height) from the 2013 survey for SFA 29 West. Points represent tow locations.

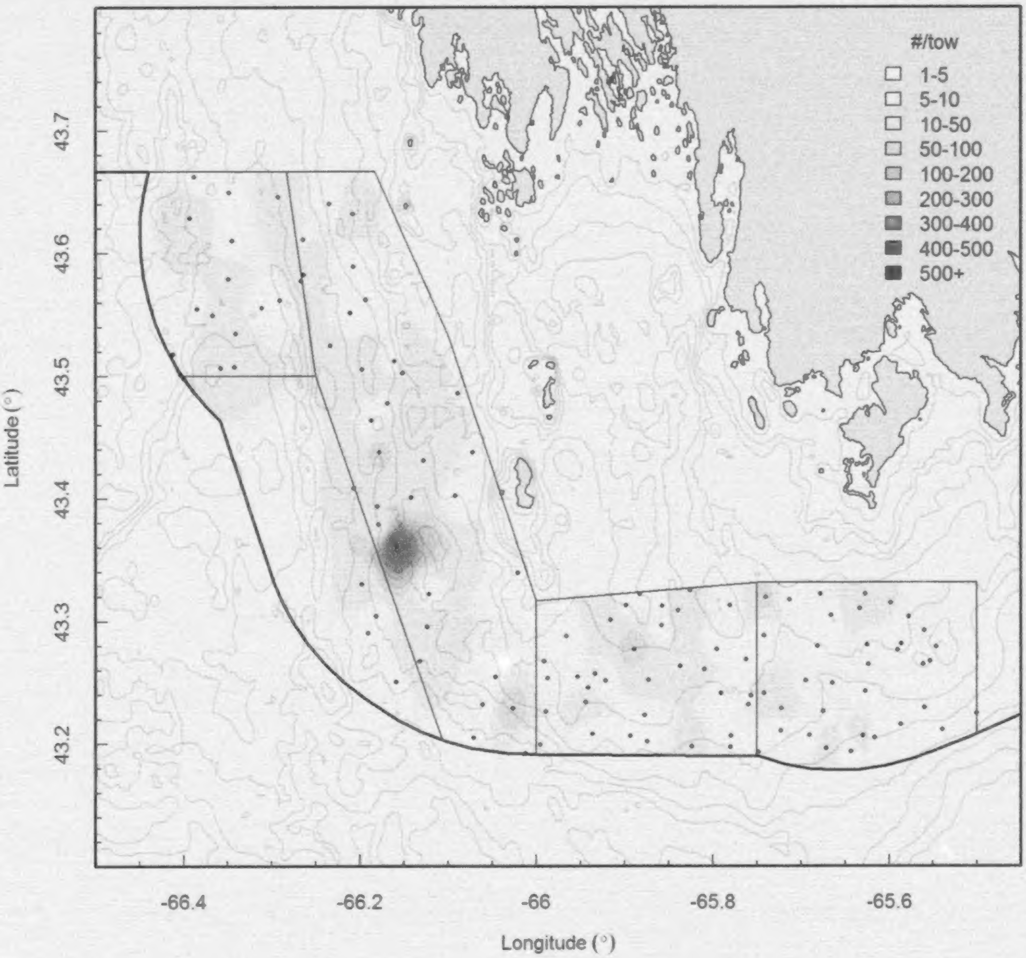

Figure 26. Spatial density (numbers/tow) distribution of recruit scallops (90–99 mm shell height) from the 2013 survey for SFA 29 West. Points represent tow locations.

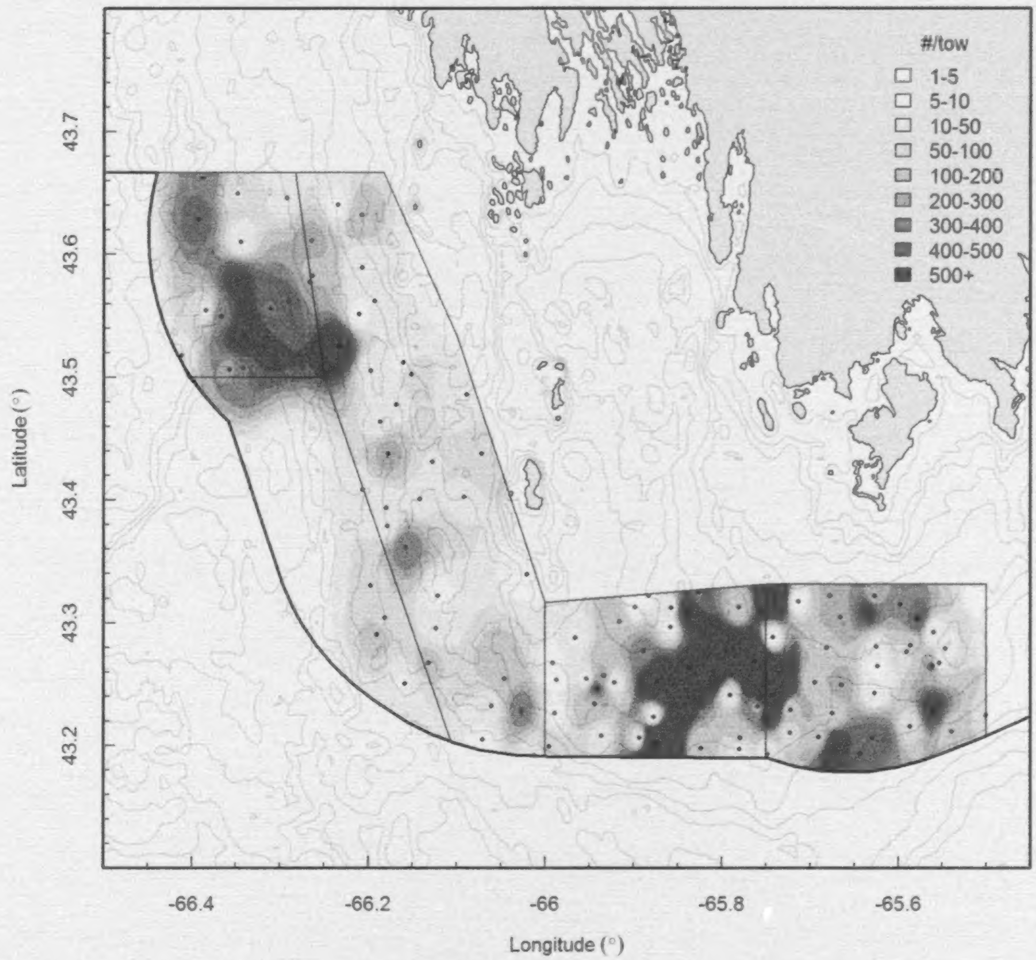

Figure 27. Spatial density (numbers/tow) distribution of pre-recruit scallops (< 90 mm shell height) from the 2013 survey for SFA 29 West. Points represent tow locations.

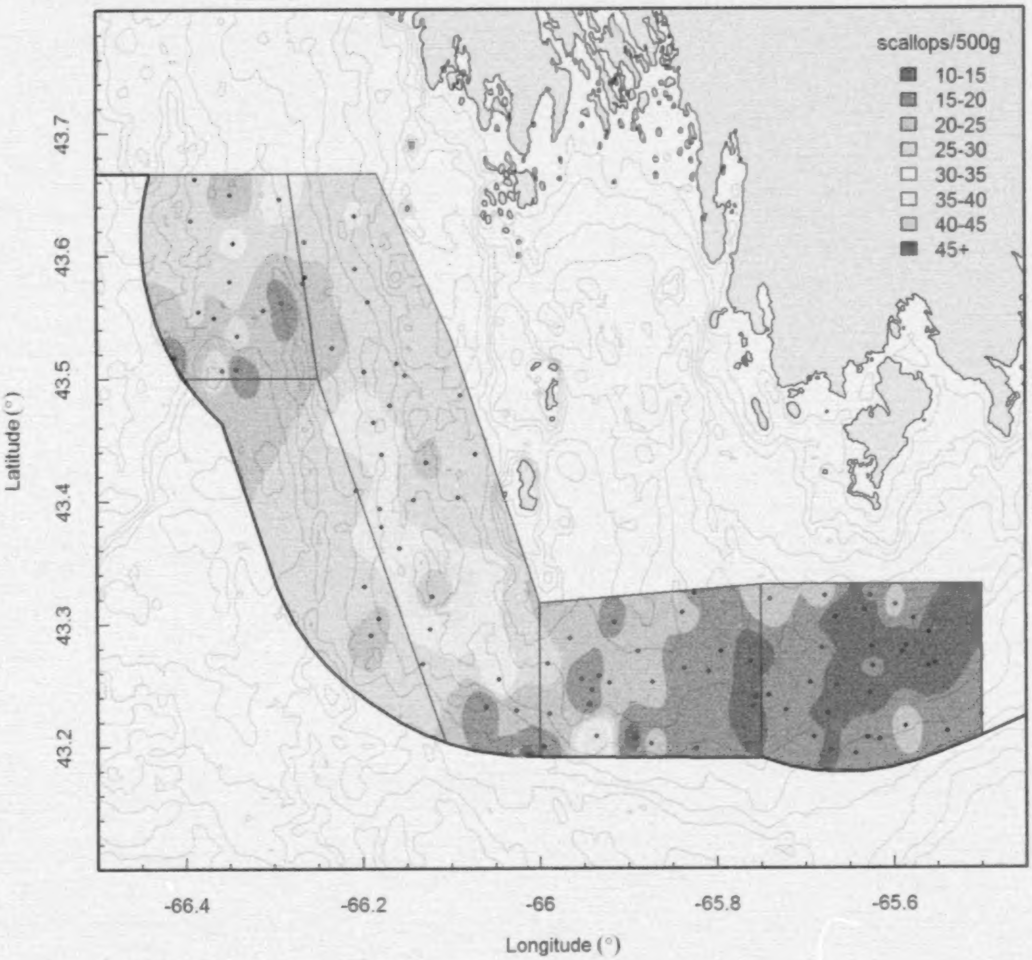

Figure 28. Spatial distribution of estimated meat count of commercial size scallops (≥ 100 mm shell height) from the 2013 survey for SFA 29 West. Points represent tow locations.

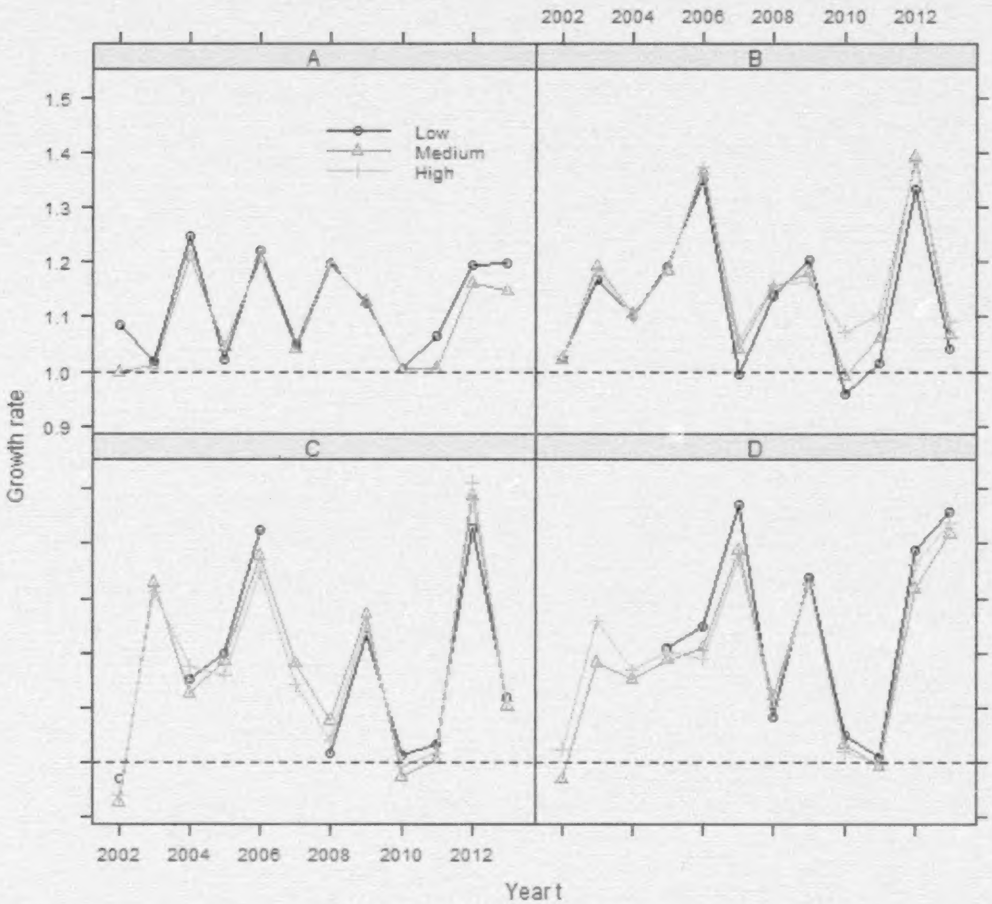

Figure 29. Growth rates for biomass from year t-1 to year t by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2002 to 2013.

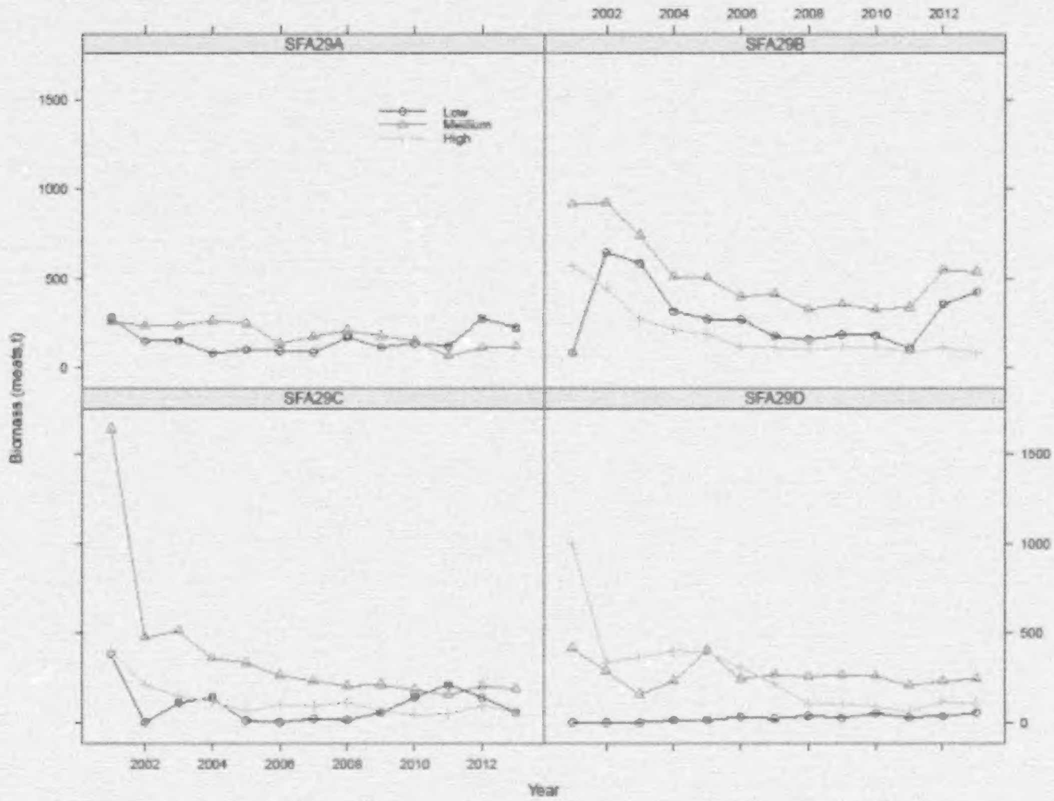

Figure 30. State-space model estimate of population biomass (meats, t) for commercial size scallops by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2013.

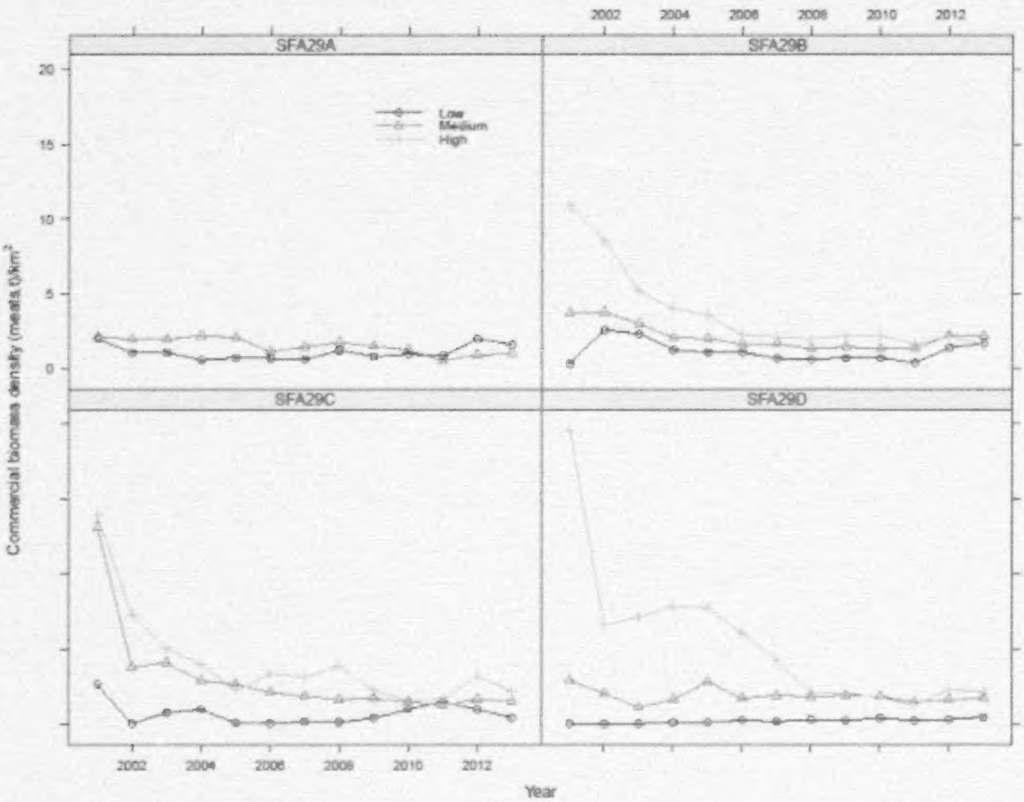

Figure 31. State-space model estimate of population biomass density (meats, t/km^2) for commercial size scallops by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2013.

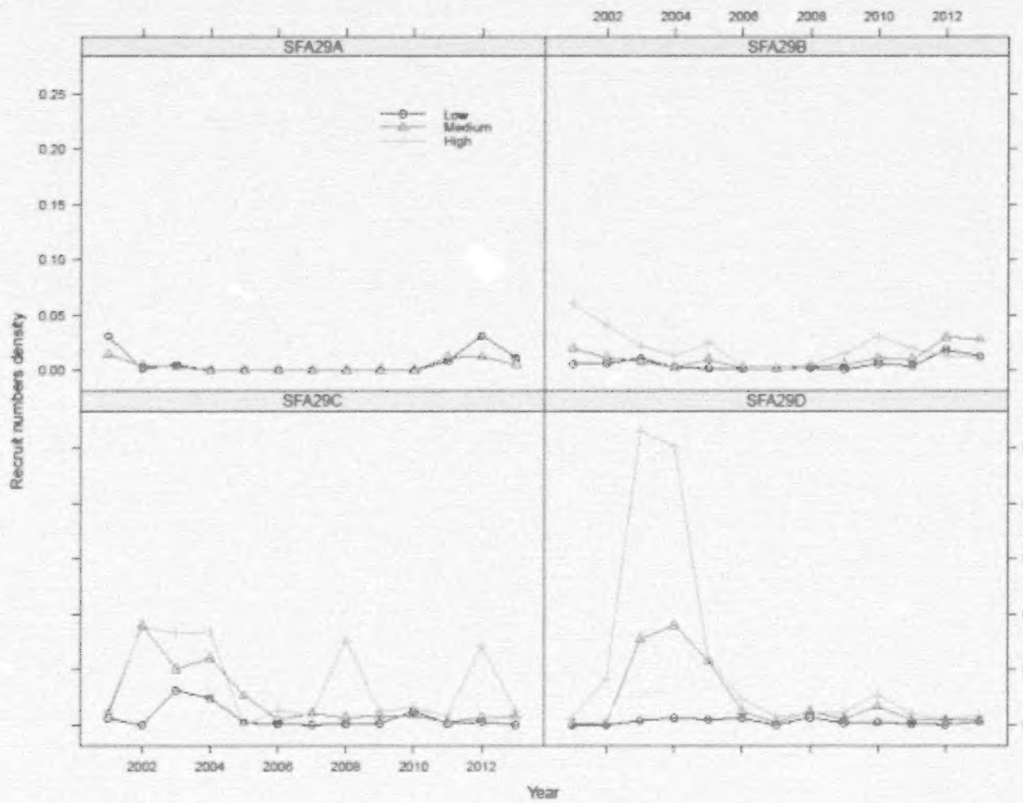

Figure 32. State-space model estimate of population density of recruit size scallops by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2013.

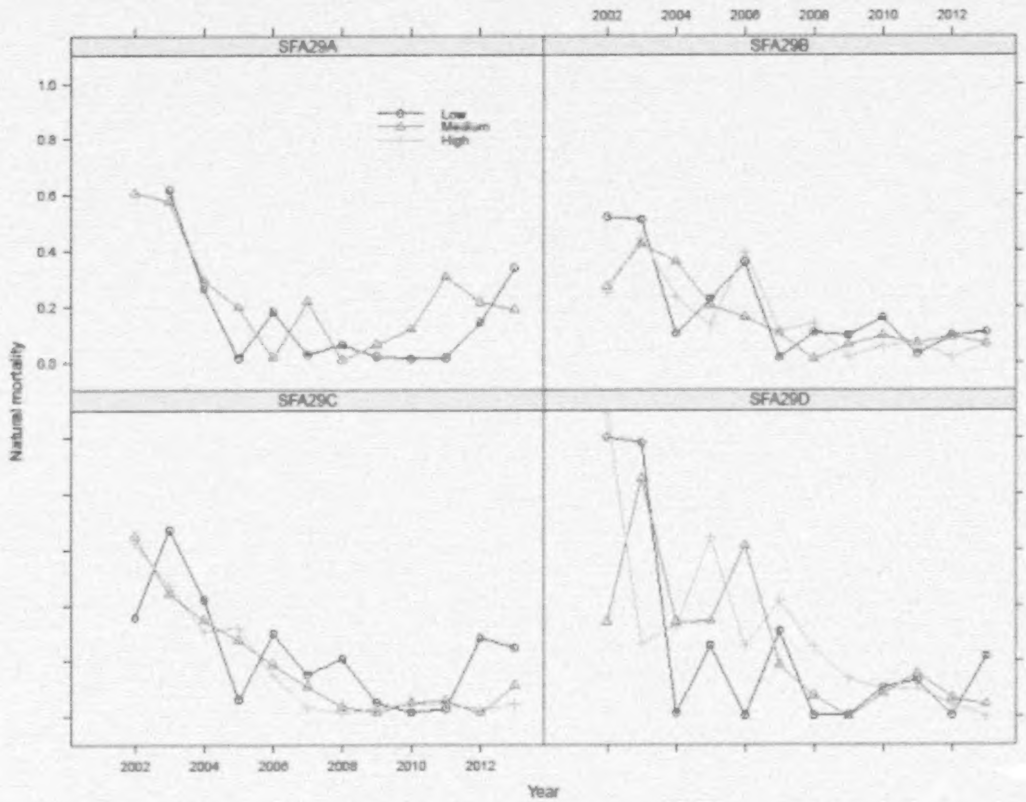

Figure 33. State-space model estimate of natural mortality for commercial size scallops by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2013.

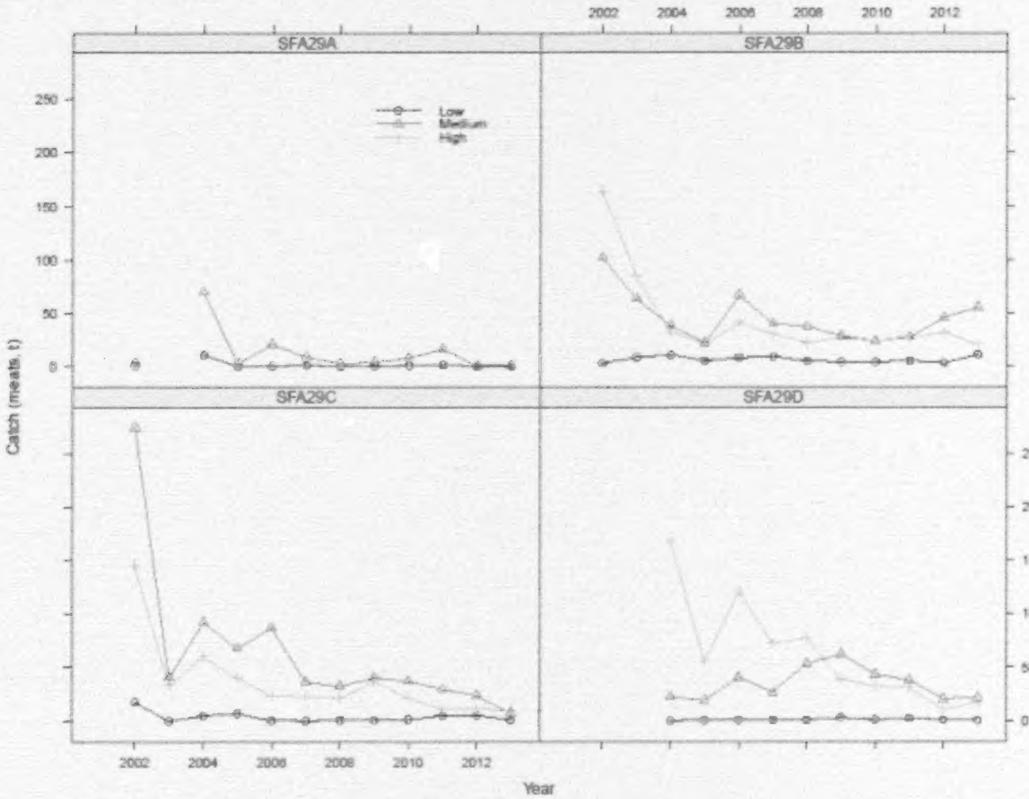

Figure 34. State-space model estimate of commercial catch (meats, t) by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2013.

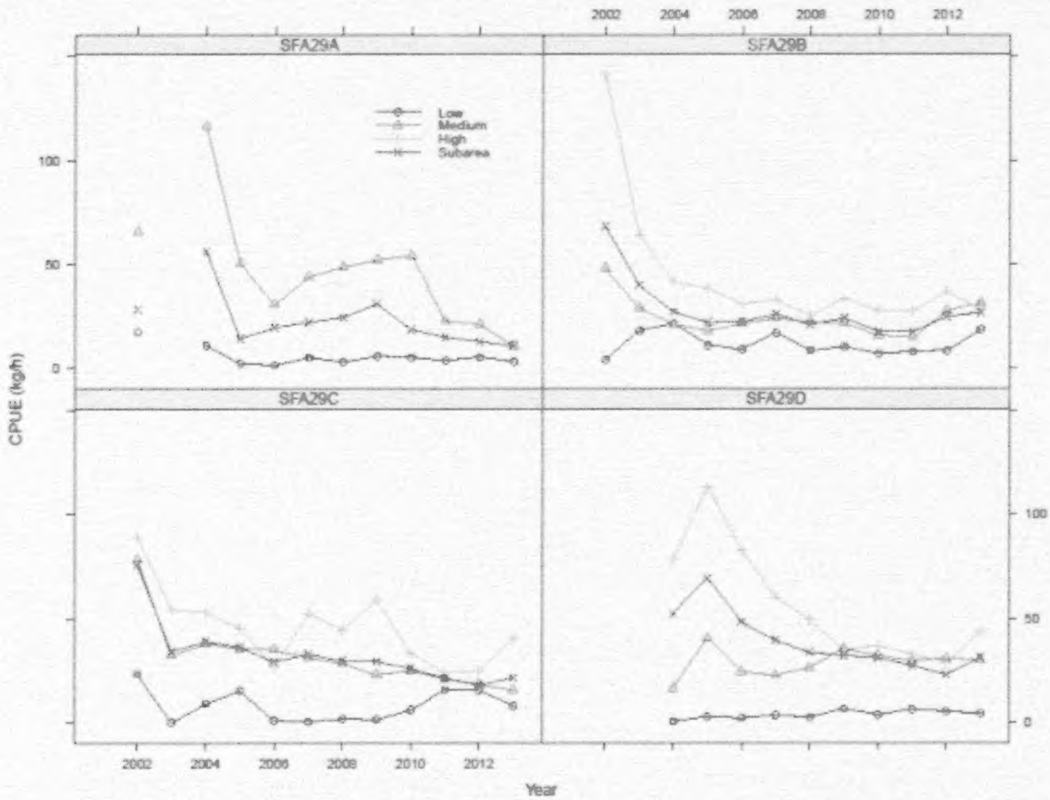

Figure 35. State-space model estimate of commercial catch rate (kg/h) by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2013. The blue line labelled as subarea refers to the catch rate for the subarea as a whole.

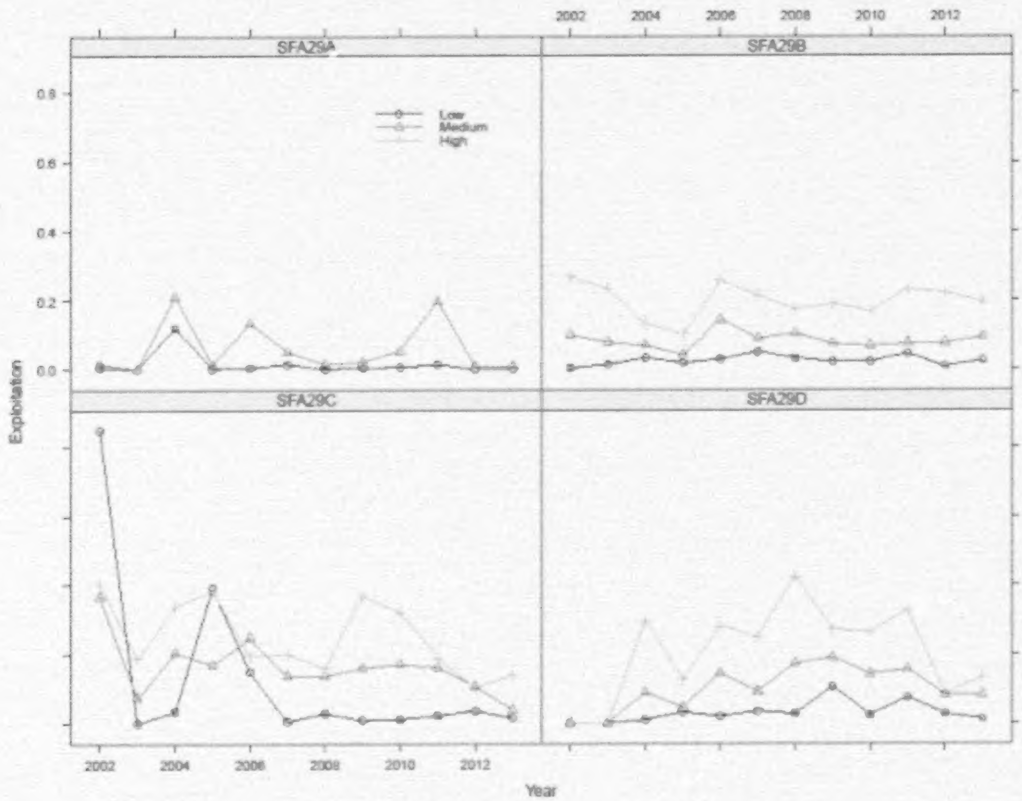

Figure 36. State-space model estimate of exploitation by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2013.

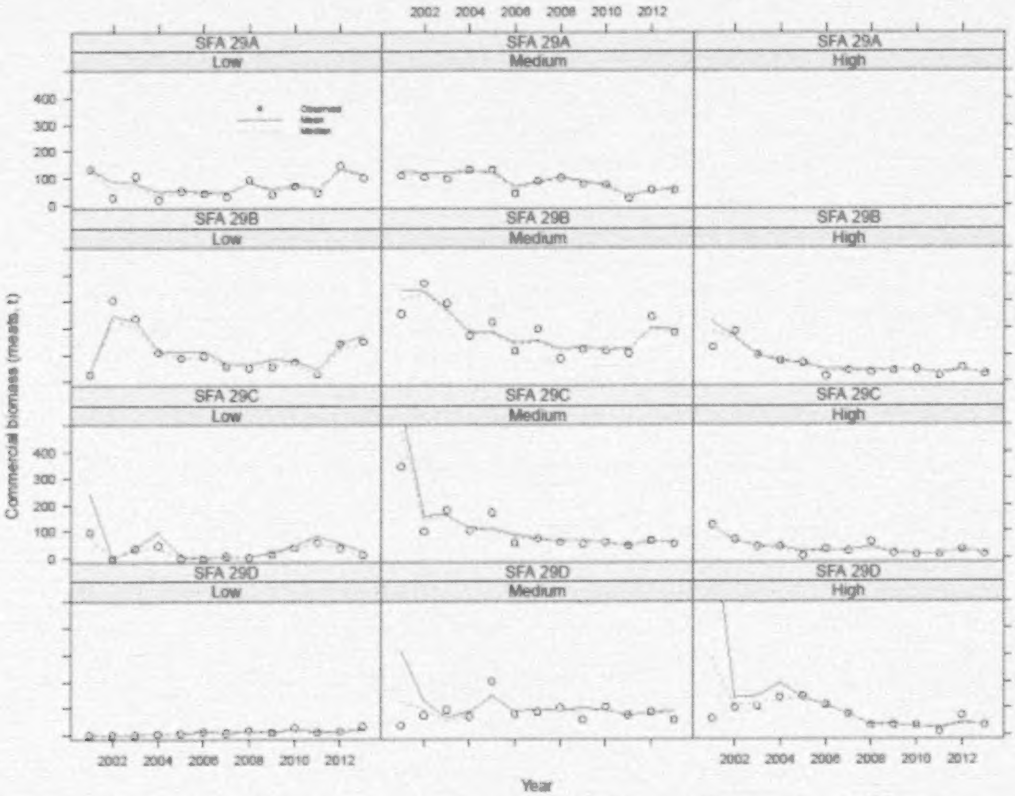

Figure 37. Fit of the state-space model to survey commercial biomass estimates by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2013.

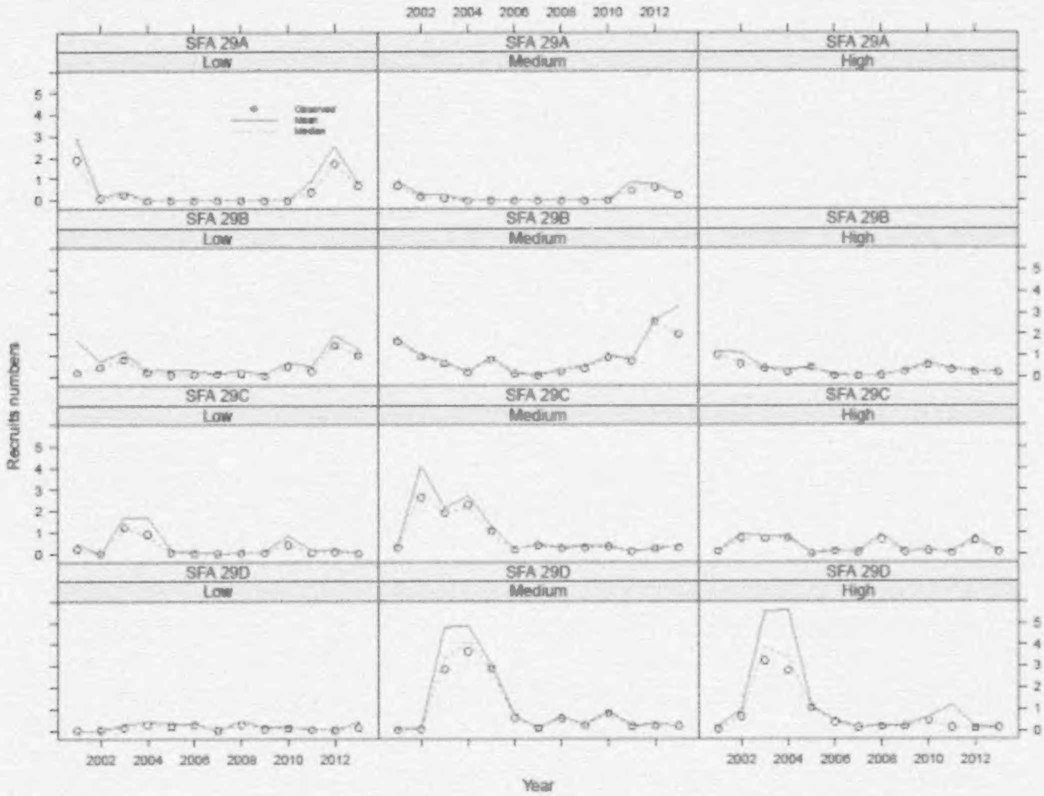

Figure 38. Fit of the state-space model to survey recruit numbers by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2013.

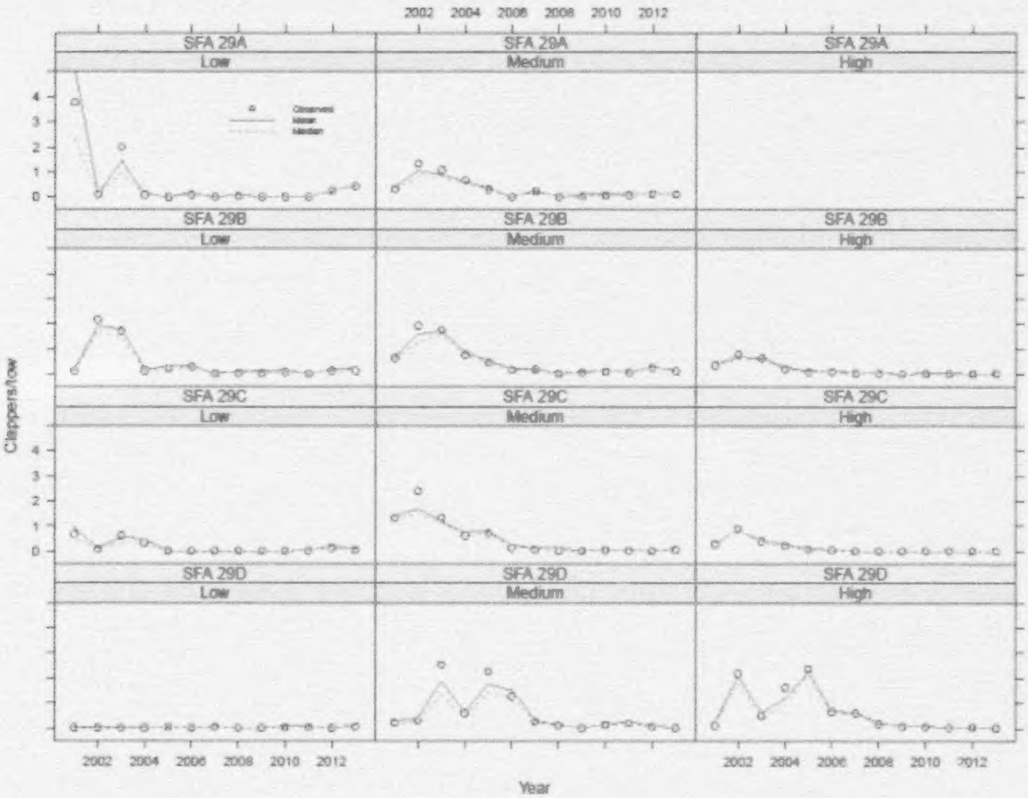

Figure 39. Fit of the state-space model to survey clapper numbers by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2013.

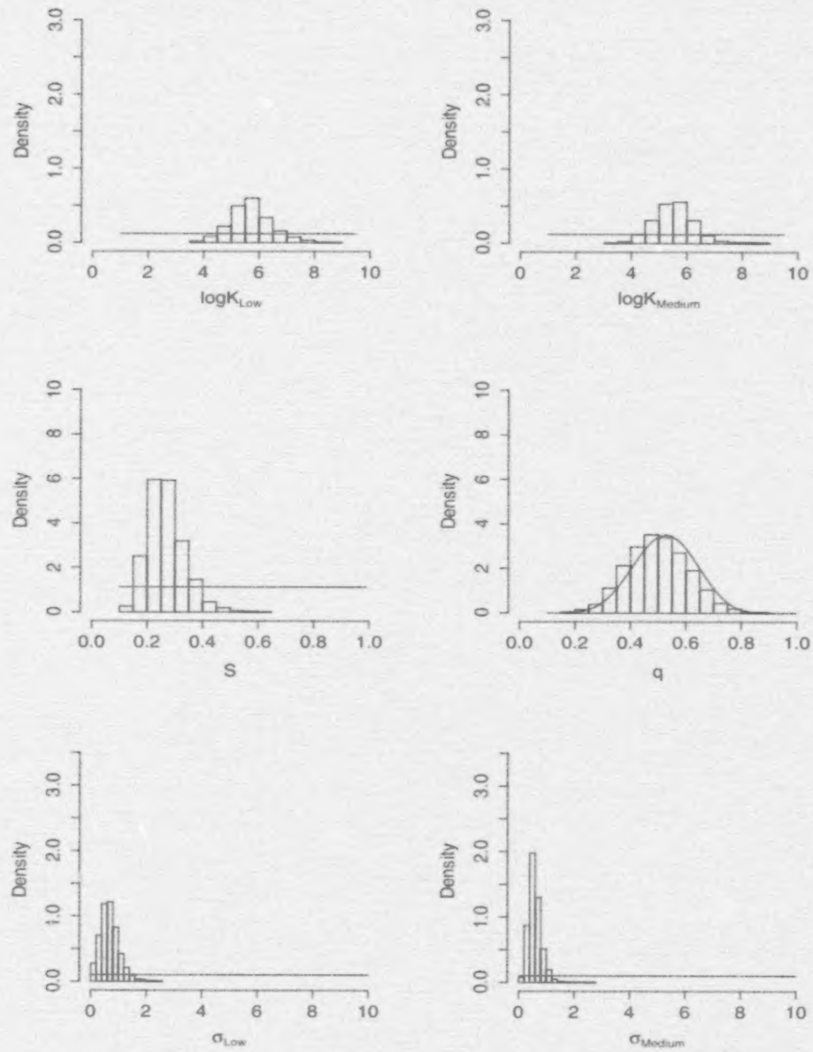

Figure 40. Comparison of prior (solid line) and posterior (histogram) densities from the state-space assessment model for SFA 29A.

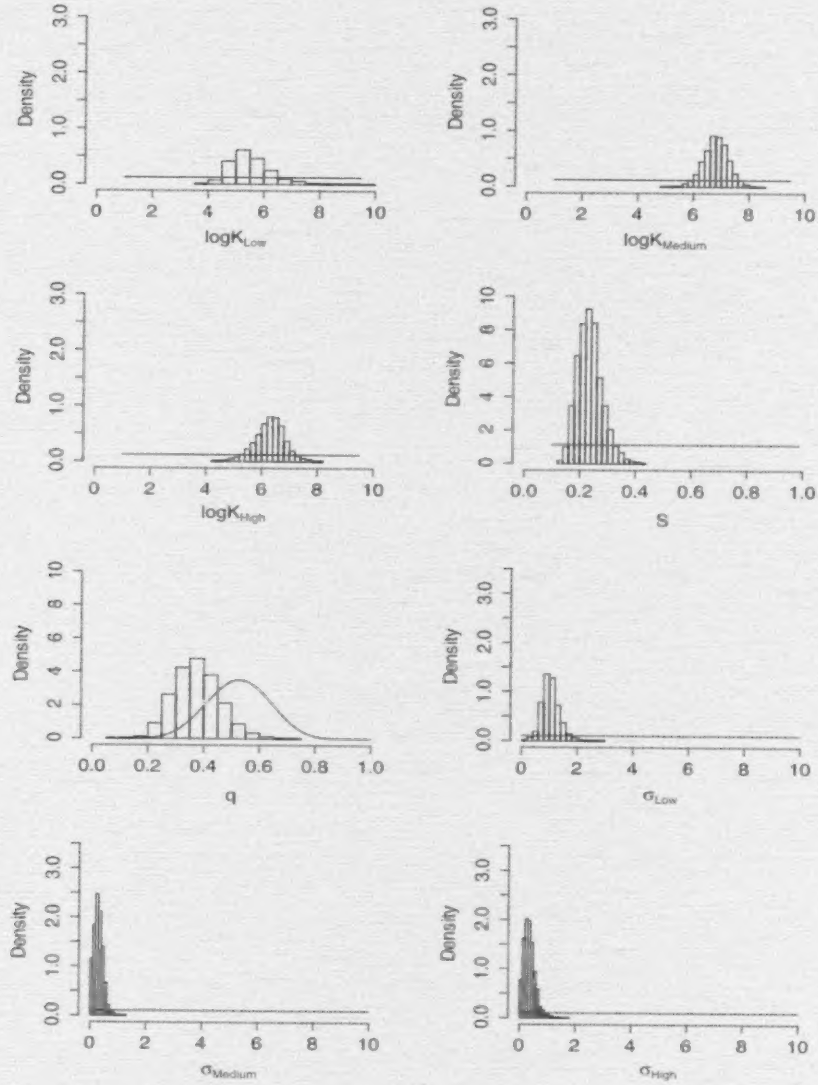

Figure 41. Comparison of prior (solid line) and posterior (histogram) densities from the state-space assessment model for SFA 29B.

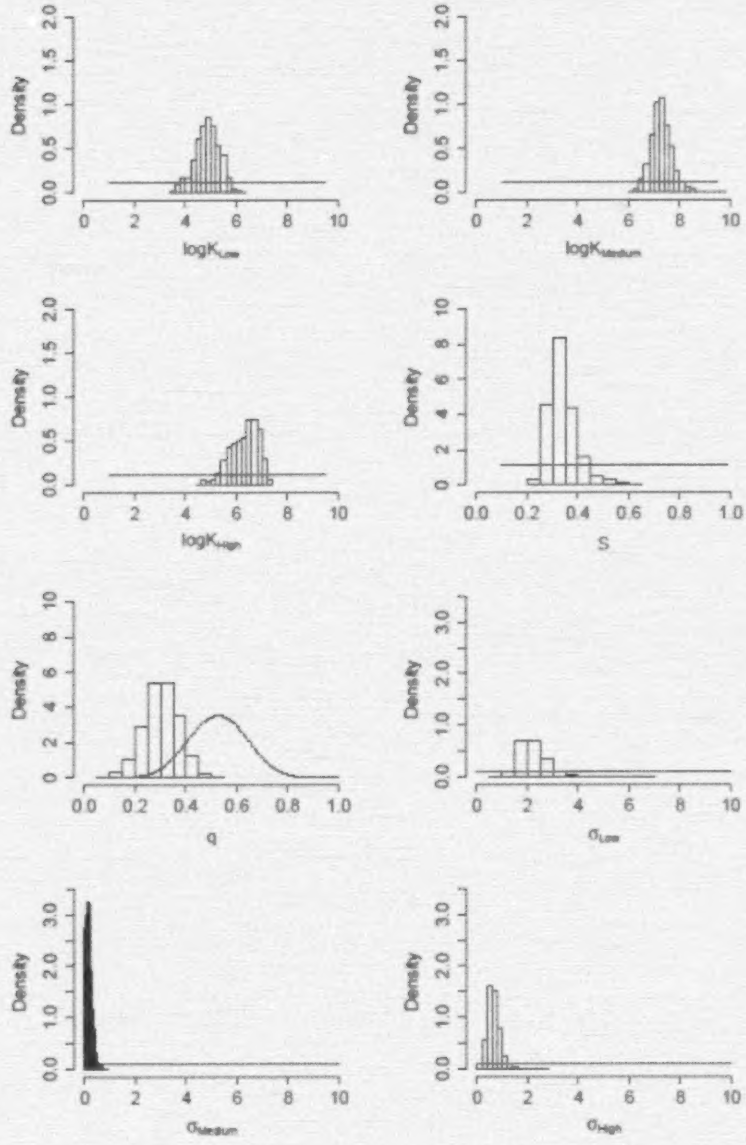

Figure 42. Comparison of prior (solid line) and posterior (histogram) densities from the state-space assessment model for SFA 29C.

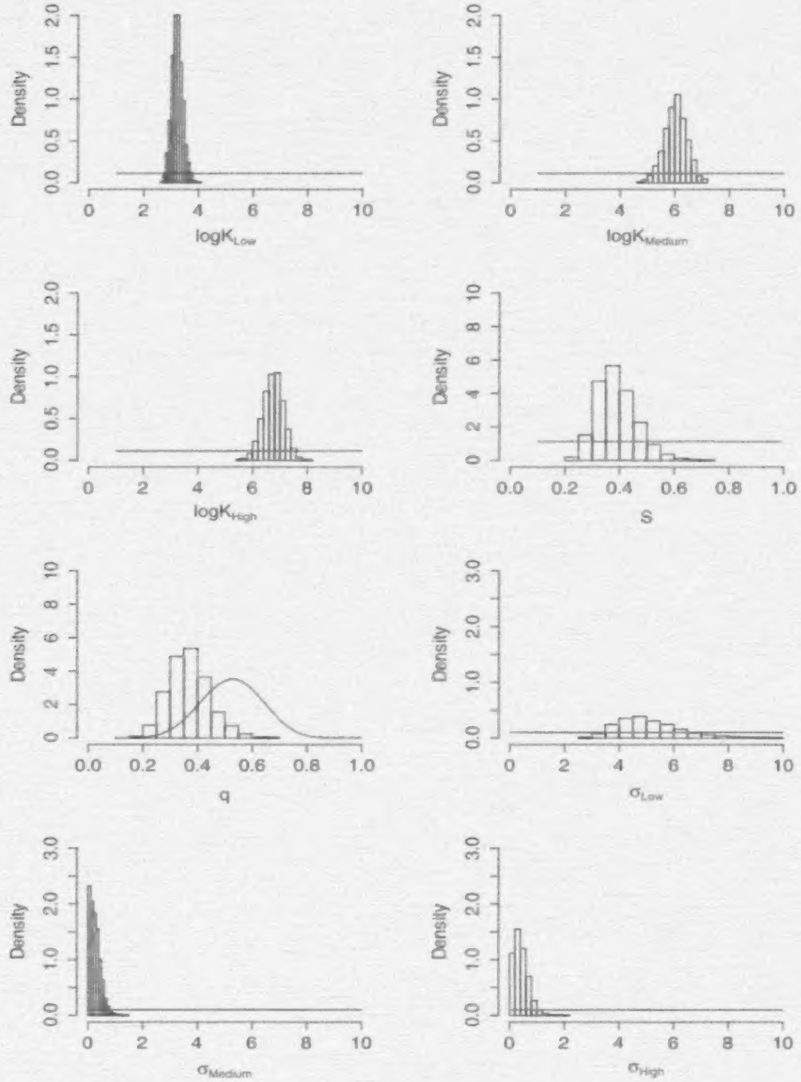

Figure 43. Comparison of prior (solid line) and posterior (histogram) densities from the state-space assessment model for SFA 29D.

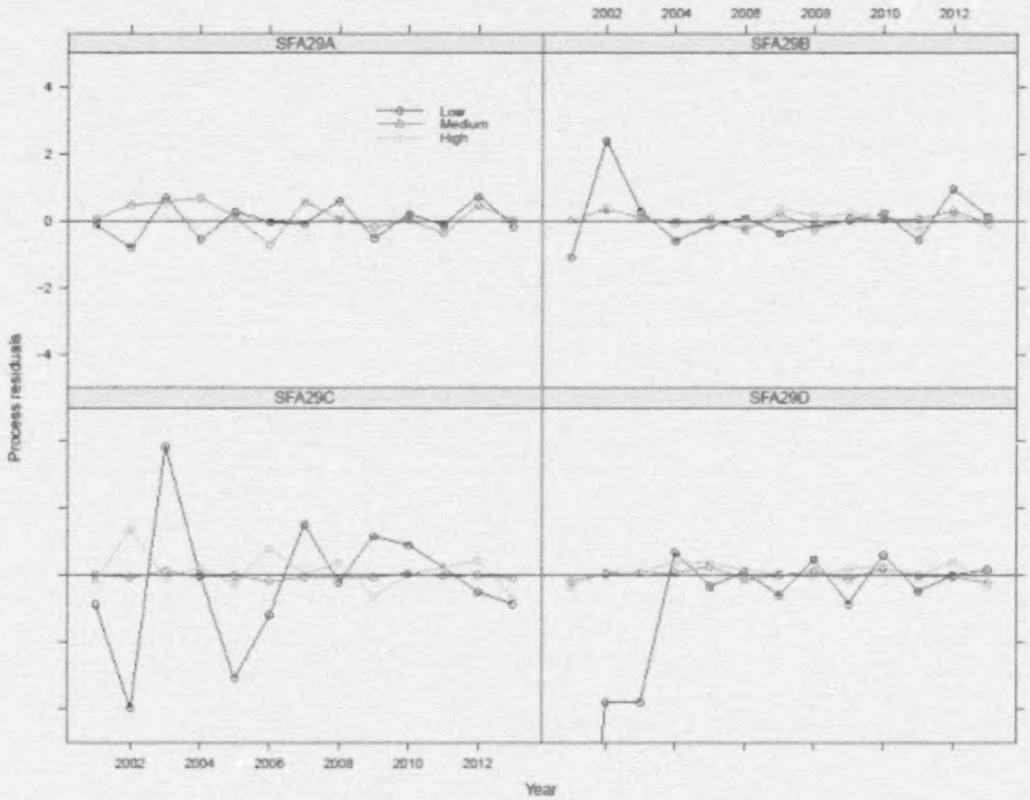

Figure 44. Mean posterior process errors from state-space model for scallops by Low [0, 0.3), Medium [0.3, 0.6) and High [0.6, 1.0) categories of habitat suitability probabilities in SFA 29 West from 2001 to 2013.

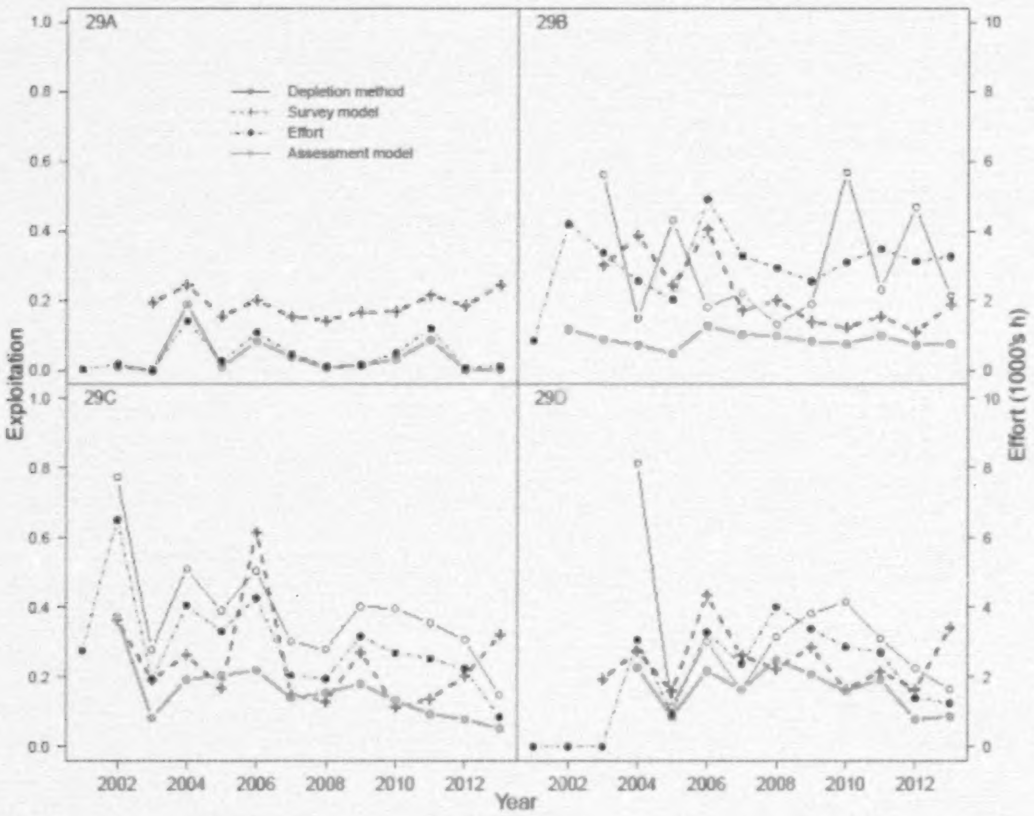

Figure 45. Comparison of exploitation estimates from the state-space habitat-based population model, the depletion method, survey model, and the total annual fishing effort for commercial size scallops in SFA 29 West from 2001 to 2013, subareas A to D. Note that reliable estimates of exploitation for subarea A were not obtained for the depletion method.

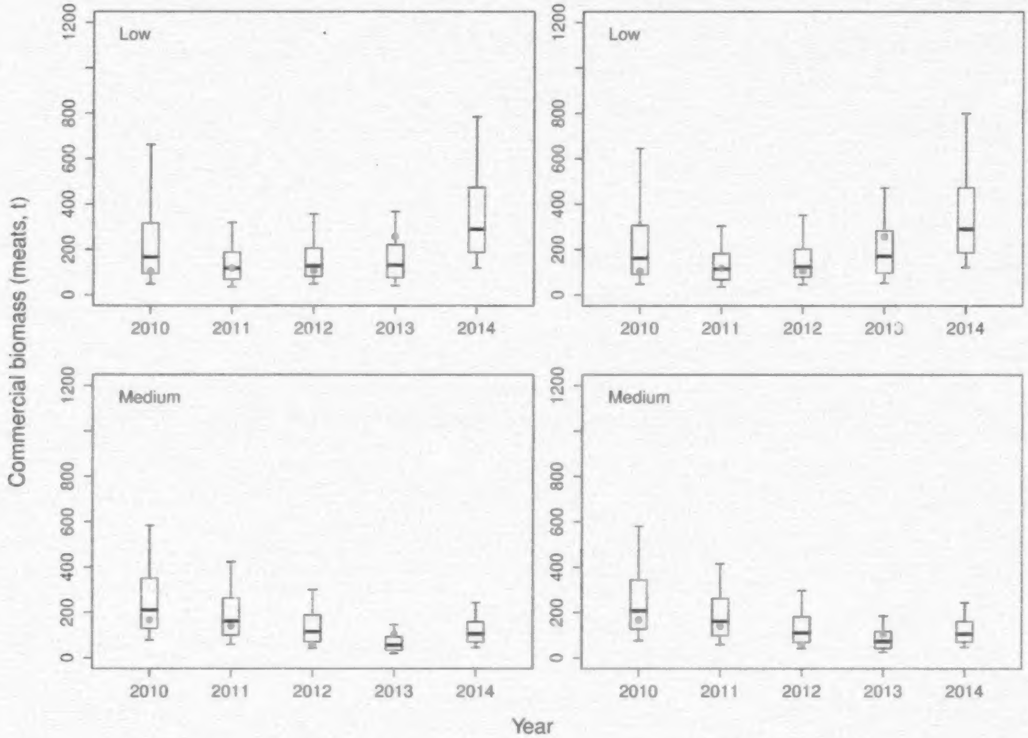

Figure 46. Evaluation of the model projection performance by Low ([0, 0.3)) and Medium ([0.3, 0.6)) categories of habitat suitability probabilities in SFA 29A. Box and whisker plots summarise posterior distribution of commercial size biomass in year t based on model fit to year t-1 (e.g. 2009 predictions based on data up to 2008). The upper and lower edges of the box represent the 0.25 and 0.75 quantiles while the upper and lower whiskers indicate the 0.1 and 0.9 quantiles. The horizontal line in the box indicates the median. The red dots represent the estimate of the biomass in year t using data up to and including year t, from the Bayesian state-space assessment model. Left panel predictions made using condition estimates from previous year and right panel predictions were made using the actual condition estimates for the predicted year.

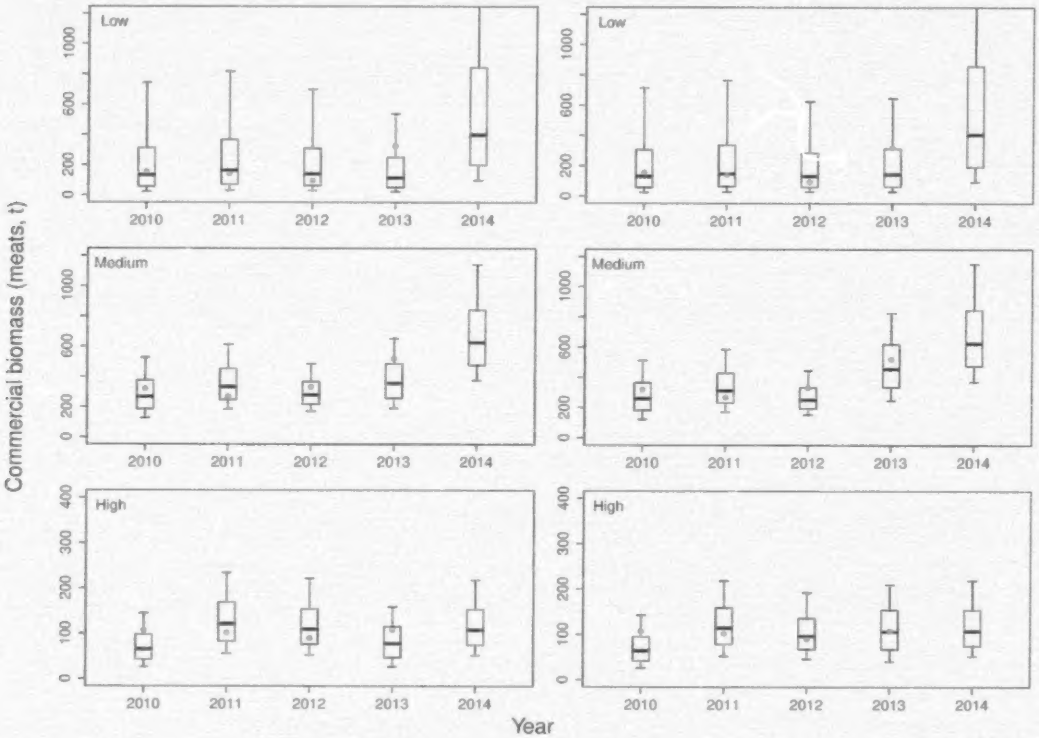

Figure 47. Evaluation of the model projection performance by Low ([0, 0.3)), Medium ([0.3, 0.6)) and High ([0.6, 1.0)) categories of habitat suitability probabilities in SFA 29B. Box and whisker plots summarise posterior distribution of commercial size biomass in year t based on model fit to year t-1 (e.g. 2009 predictions based on data up to 2008). The upper and lower edges of the box represent the 0.25 and 0.75 quantiles while the upper and lower whiskers indicate the 0.1 and 0.9 quantiles. The horizontal line in the box indicates the median. The red dots represent the estimate of the biomass in year t using data up to and including year t, from the Bayesian state-space assessment model. Left panel predictions made using condition estimates from previous year and right panel predictions were made using the actual condition estimates for the predicted year.

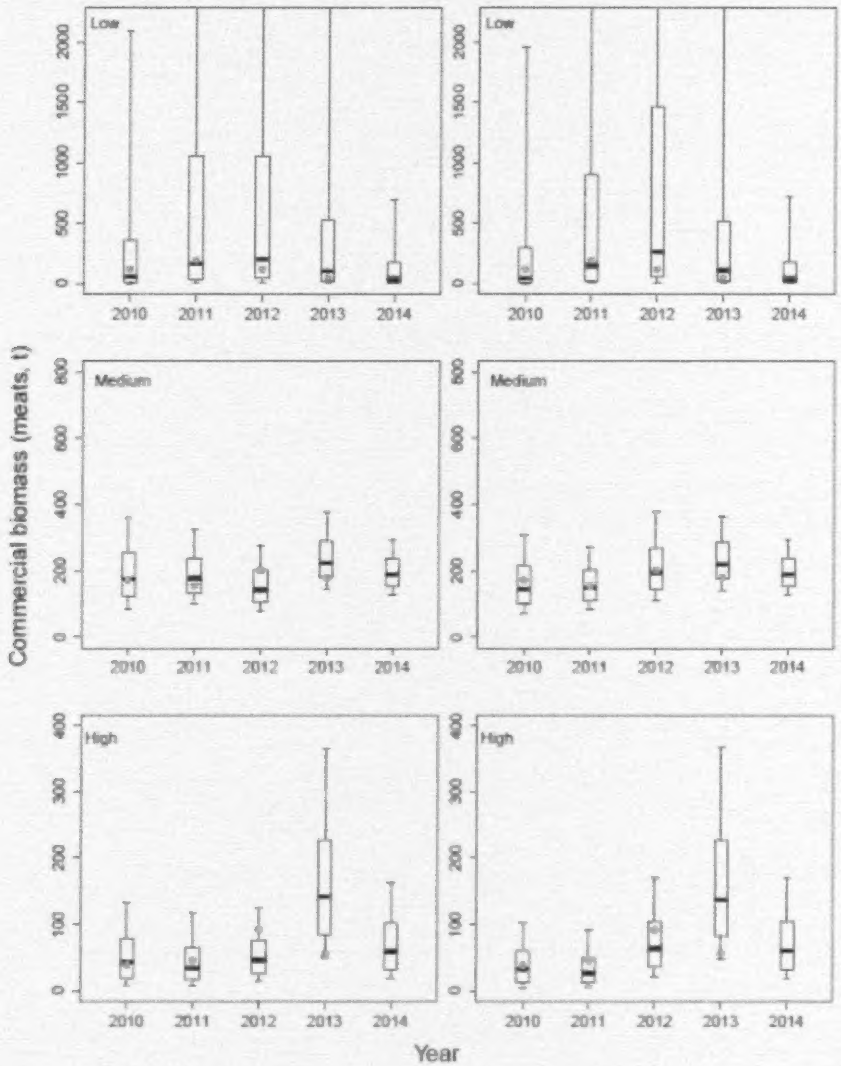

Figure 48. Evaluation of the model projection performance by Low ([0, 0.3)), Medium ([0.3, 0.6)) and High ([0.6, 1.0)) categories of habitat suitability probabilities in SFA 29C. Box and whisker plots summarise posterior distribution of commercial size biomass in year t based on model fit to year t-1 (e.g. 2009 predictions based on data up to 2008). The upper and lower edges of the box represent the 0.25 and 0.75 quantiles while the upper and lower whiskers indicate the 0.1 and 0.9 quantiles. The horizontal line in the box indicates the median. The red dots represent the estimate of the biomass in year t using data up to and including year t, from the Bayesian state-space assessment model. Left panel predictions made using condition estimates from previous year and right panel predictions were made using the actual condition estimates for the predicted year.

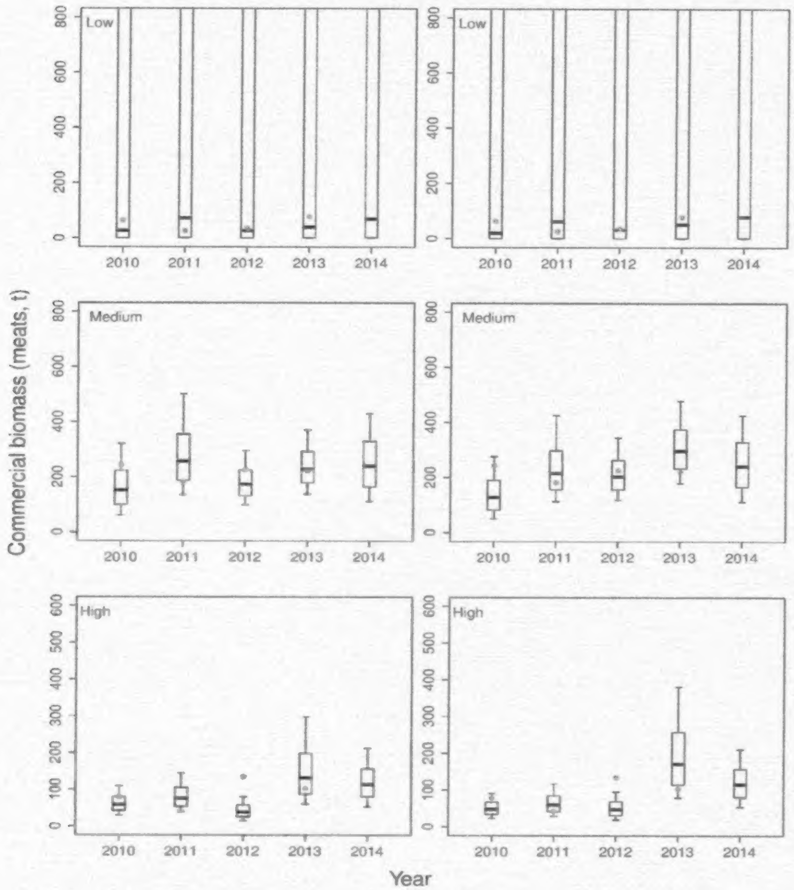

Figure 49. Evaluation of the model projection performance by Low ([0, 0.3)), Medium ([0.3, 0.6)) and High ([0.6, 1.0)) categories of habitat suitability probabilities in SFA 29D. Box and whisker plots summarise posterior distribution of commercial size biomass in year t based on model fit to year t-1 (e.g. 2009 predictions based on data up to 2008). The upper and lower edges of the box represent the 0.25 and 0.75 quantiles while the upper and lower whiskers indicate the 0.1 and 0.9 quantiles. The horizontal line in the box indicates the median. The red dots represent the estimate of the biomass in year t using data up to and including year t, from the Bayesian state-space assessment model. Left panel predictions made using condition estimates from previous year and right panel predictions were made using the actual condition estimates for the predicted year.

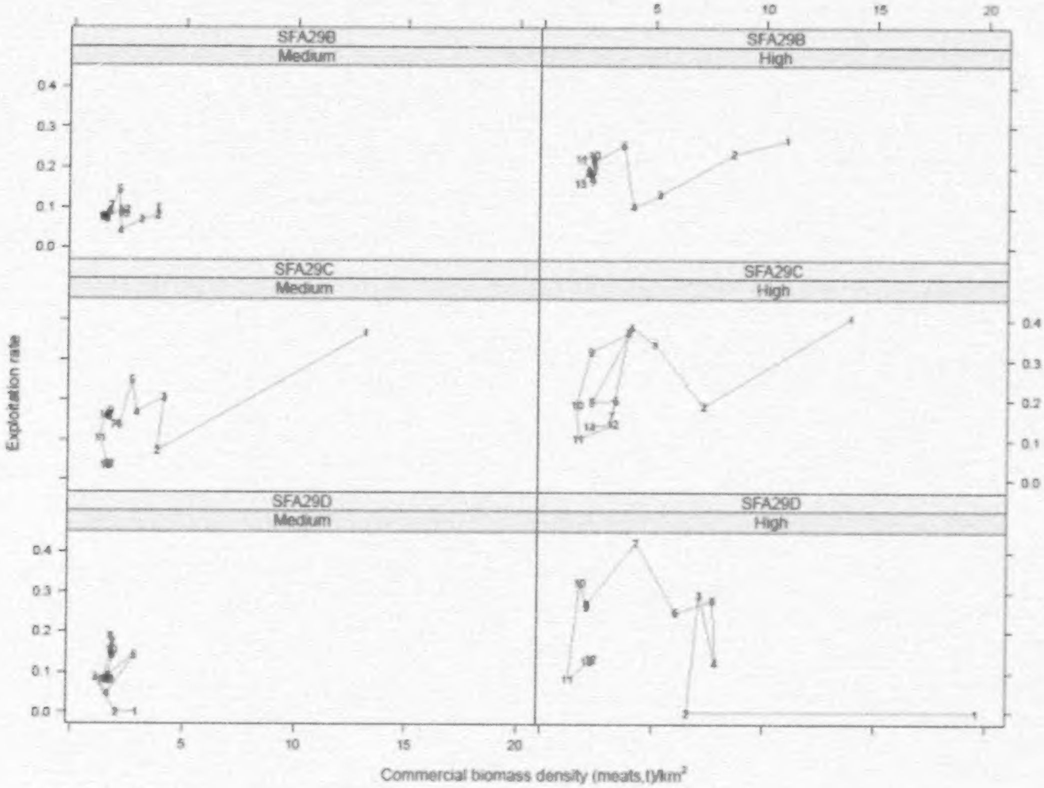

Figure 50. Phase plots for the Medium and High suitability category areas. Number labels for points refer to the year of the survey. For example, the label 3 refers to 2003 and the commercial size density prior to the fishery in 2004 and the corresponding exploitation rate is for the 2004 fishery. Note that the survey occurs after the fishery in any given year.

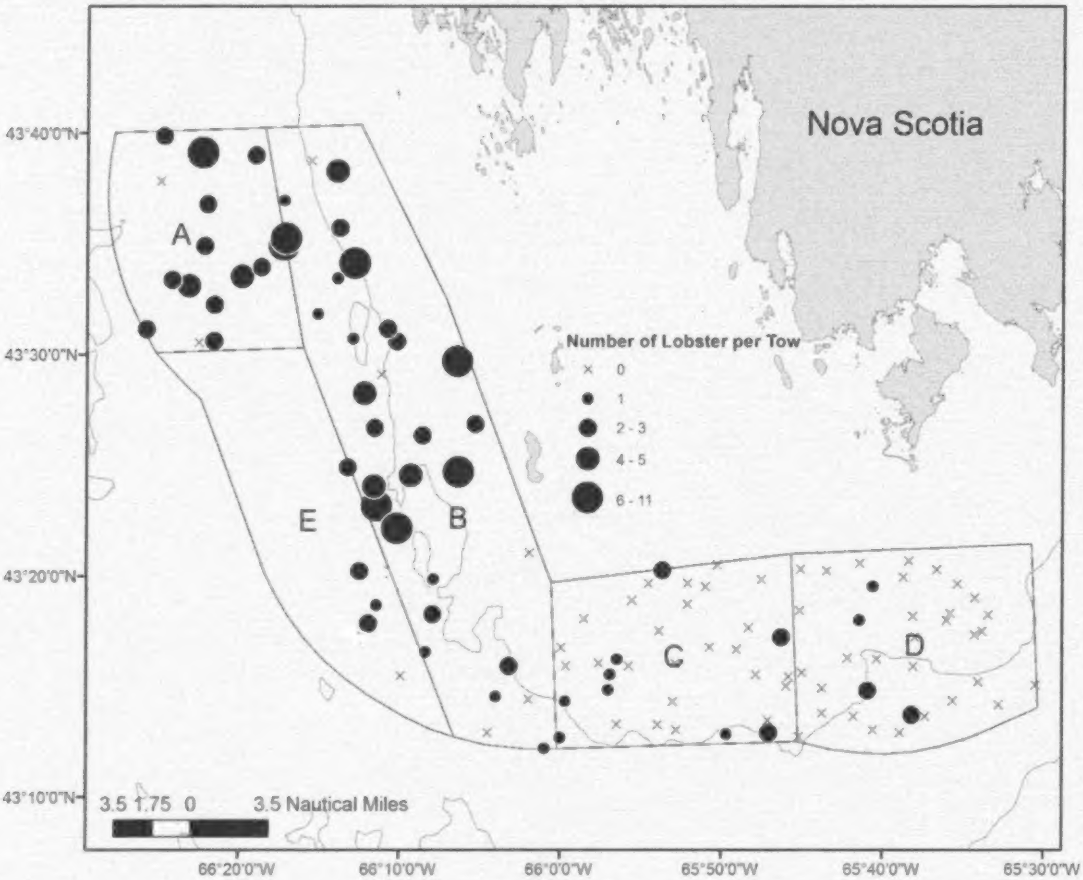

Figure 51. Location and number of lobsters caught in SFA 29 West during the 2013 survey. Crosses indicate locations where no lobsters were caught.

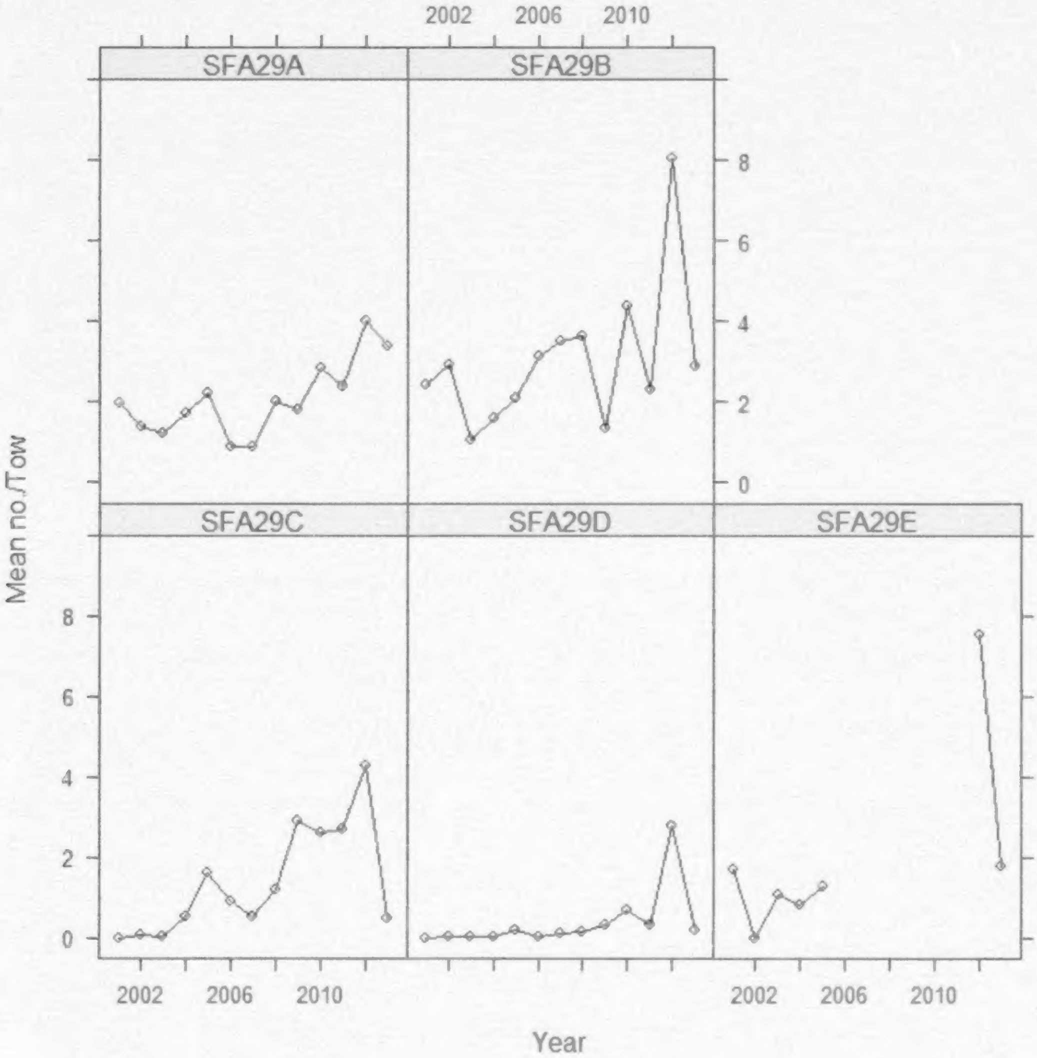

Figure 52. Number of lobsters per tow from scallop surveys in SFA 29 West from 2001 to 2013. Geophysical strata used for design.

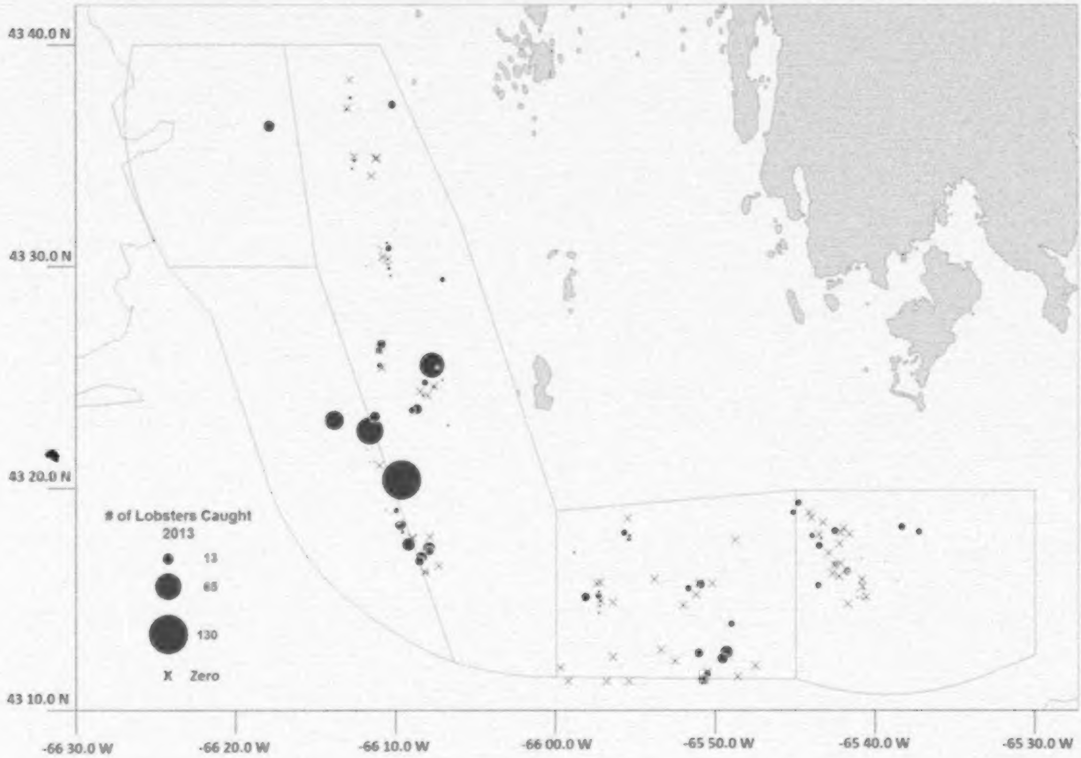

Figure 53. Location and number of lobsters caught in SFA 29 West in 2013 from observed scallop fishing trips. Crosses indicate locations where no lobsters were captured.